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No. 18.

Colonial Museum and Geological Survey of New Zealand.

SIR JAMES HECTOR, K.C.M.G., M.D., F.R.S.,
DIRECTOR.

REPORTS

OF

GEOLOGICAL EXPLORATIONS

DURING 1886-87,

WITH MAPS AND SECTIONS.

PUBLISHED BY COMMAND.

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REPORTS OF THE GEOLOGICAL SURVEY.

PROGRESS REPORT, 1887.

THE following reports record the survey work done during the year 1886 and part of the present year. The districts examined have been as follow:—

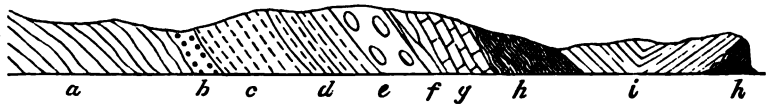
In the South Island:

1. Southern Amuri district.
2. Malvern Hills, Canterbury District.
3. South Canterbury District.
4. Otago District, from Oamaru to Taieri.
5. South Otago District, from Waikawa to Hokonui Mountains.
6. North-west Otago, from Wakatipu Lake to Big Bay.
7. West Coast, Buller Valley, Mokihinui, and Collingwood.

In the North Island:

8. Upper Wanganui and Mokau district.
9. Napier District and Urewera country.
10. East Cape district.
11. Tarawera district.
12. Kaipara district.

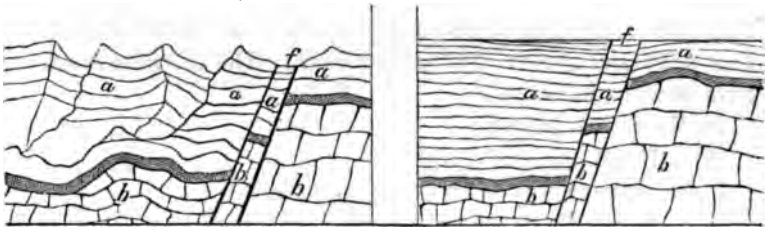
The first of the reports to be referred to was the examination by Mr. McKay of certain points connected with the geology of Kaikoura Peninsula, it having been asserted by Professor Hutton that here there is proof of the unconformable relation of the Grey-marls to the Amuri limestone.*



Kaikoura Peninsula, north-west to south-east. *a*. Grey sandstones with coal and plants. *b*. Black-grit. *c*. Shales with ferruginous concretions. *d*. Sandstones, micaceous and ferruginous, with sulphur efflorescence. *e*. Sandstone with large spherical concretions. *f*. Cherty limestone with black flints. *g*. Grey limestone, jointed. *h*. Calcareous shale, much contorted. *i*. Grey or brown argillaceous sandstone (Grey-marls).

* Jour. Geol. Soc., Lond., Vol. XLI., p. 273.

The above section shows the arrangement of the strata that are involved in the structure of the Kaikoura Peninsula, taken from my field notes of 1873. The section is from the east headland (at *h*) along the south side of the peninsula, and displays the western half of a syncline that contains the complete sequence from the Grey-marls (*i*) down to the Amuri group (*a*). From its position and the mineral character of the beds it probably represents the western of the two synclines that are present at the Amuri Bluff.



A. Section. B. Plan.

a. Marls. *b*. Limestone with concretionary layer interposed.

The unconformity is supposed by Captain Hutton to occur between the two upper beds of the series; but I find in my note-book also a section and plan, which I here reproduce, as it probably refers to nearly the same locality as that given in illustration by Professor Hutton, but affording a very different explanation from his, the apparent discordance of the beds being due partly to faulting and partly to the manner in which motion has produced corrugation in the beds of one mineral character, while the underlying limestone has been jointed, and the overlying argillaceous beds only compressed.

The facts adduced by Mr. McKay are quite in accordance with my observations, and show, moreover, the existence of the Weka Pass stone in the south-eastern extremity of the peninsula —a circumstance which has hitherto been overlooked. The rock in question, as a calcareous sandstone, is developed to a thickness of at least 40ft., and separated from the underlying Amuri limestone by a bed of the same concretionary nodular structure as seen in the Weka Pass and in both the principal sections at Amuri Bluff. The strike and dip of the beds are the same, and there are no other evidences of unconformity between the Weka Pass stone and the Amuri limestone at this place.

The Grey-marls overlying the Weka Pass stone rest on that rock with perfect conformity, and are not, as shown in published sections, in contact with the contorted beds of Amuri

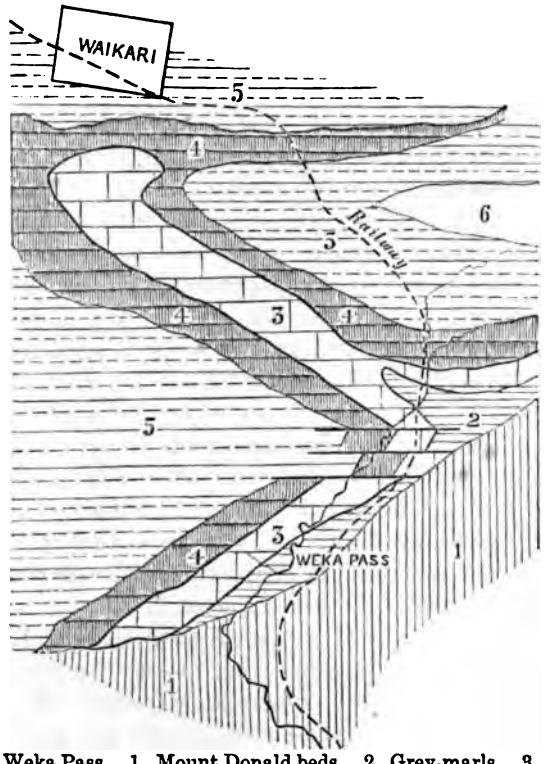
limestone at the east head of the peninsula; but the evidences of faulting are here so manifest that this section cannot be taken as proof of an unconformity; besides which, the Weka Pass stone is absent at East Head, and, were it not hidden by a fault, could hardly have thinned out altogether in a distance of less than a mile. Samples of the concretionary layer parting the Weka Pass stone from the Amuri limestone were forwarded for examination, and, though a close examination of the limestones was made for fossils, none were found. Teeth of a shark, probably Carcharodon, were obtained from the Grey-marls on the north side of the peninsula, but otherwise, save for the occasional occurrence of badly-preserved bones (whether saurian or cetacean could not be determined), the Grey-marls are also without fossils.

The occurrence of the Weka Pass stone in the Kaikoura Peninsula is most important, since it shows that former surveys have not been sufficiently accurate to determine its presence, and, consequently, as the sequence there has been imperfectly understood, such former work cannot be used as disproving the unity of the Cretaceo-tertiary formation and the conformity of the Grey-marls to the Amuri limestone. This work also is important from another point of view. Mr. McKay described last year the same rocks occurring along the south-east flanks of the Inland Kaikoura, and showed that there the Weka Pass stone and Grey-marls overlie the Amuri limestone conformably, and this in the absence of any development of Lower or Middle Tertiary rocks. As it has been maintained by some that the Weka Pass stone does not reach north of the Hurunui River, while the Grey-marls certainly do so, it was held that the latter at Amuri Bluff and in Kaikoura Peninsula rested with unconformity on the Amuri limestone at those places.

At the Weka Pass it is not in dispute that all three members of the group are present—viz., (1) Grey-marls, (2) Weka Pass stone, and (3) Amuri (concretionary) limestone; but Professor Hutton maintains the conformity of the two first mentioned with (4) the Mount Donald (Lower Miocene) beds, and their unconformity on the Amuri limestone. Fossils are rare, and in this case cannot be relied on, owing to imperfections in the way collections have been made. The unconformity between No. 4, the Mount Donald beds, and Grey-marls and underlying beds, seemed clear to me in 1874, as recorded in my note-book in the following plan and section, which I last year revised, but

only amended by the clearer evidence afforded by the railway cuttings made since my first visit:—

a. Upper Eocene (Mount Donald beds). *b*. Grey-marls. *c*. Weka Pass stone. *d*. Amuri limestone. *e*. Saurian greensands.



Plan of the Weka Pass. 1. Mount Donald beds. 2. Grey-marls. 3. Weka Pass stone. 4. Amuri limestone. 5. Greensands. 6. Palæozoic (?).

Mr. McKay's report on the sections exhibited in the Weka Pass appear to give much the same relations to the various beds as above shown, and his discovery of definite chemical proof that the supposed fragmental layer at the base of the Weka Pass stone is truly concretionary, and that it consists of a layer of

phosphate nodules (page 84), has not only an interesting bearing on the controversy, but also an important economic aspect.

This discovery of the Weka Pass stone in the Kaikoura district is of greater importance than the mere settlement of the issues raised, the practical outcome affecting, to a great extent, the area of possibly coal-bearing rocks which underlie these upper members of the Cretaceo-tertiary formation.

Amuri Bluff.—The section embracing the Amuri limestone and the Grey-marls on the western side of the anticline was examined, and a few fossils obtained, including Pecten, Ostrea, and Rhynchonella. The oyster is the same species as that occurring in the calcareous greensands of Point Elizabeth, on the West Coast, and is here found in the Amuri limestone, and also in the calcareous sandstone above the concretionary greensand bed.

Plan of Amuri Bluff. 1. Post-tertiary. 2. Grey-marls and Weka Pass stone at base. 3. Amuri limestone. 4. Greensand. 5. Saurian beds and Lower Greensands. 6. Palæozoic.

From both exposures of Amuri Bluff the following fossils have been collected: Ostrea (as above mentioned); Pecten, two species (judging from the matrix in which it is embedded there can be no doubt that *Pecten zittelli* occurs in the Amuri limestone of Amuri Bluff). Last year Mr. McKay obtained a very similar shell from the black-grit of the Seymour River section; and Mr. Park collected from the Putataka beds, west of the Lower Waikato, a specimen that also closely resembles the *Pecten zittelli* of Hutton; Inoceramus (perhaps a Perna); Rhynchonella (*R. squamosa*); Siphonium, mentioned by Professor Hutton as apparently identical with a species found in the lower beds at Amuri Bluff; *Pentacrinitis rotatus* and *P. stellatus* (mentioned by Hutton as occurring in his Oamaru formation); teeth of Lamna; numerous Foraminifera, among others *Cristellaria haastii;* and abundance of the large fan-shaped fucoid common to the limestones of this age and the Grey-marls.

There being conformity between the Amuri limestone and the Grey-marls as seen in the syncline on the western side of the Amuri Bluff section, the same thing was observed where the limestone and Grey-marls are last seen in contact in following the beach from South Amuri Bluff to Boat Harbour.

Malvern Hills.—From an exposure of fossiliferous rock in the Selwyn River bed, at a place known as the Selwyn Rapids, Mr. McKay made a large collection of fossil shells, but, as his services were urgently required in the Otago District, only this and another locality in the near vicinity were collected from, and no stratigraphical work whatever was undertaken. The position of the beds, however, has been correctly ascertained and well described by Sir Julius von Haast, who also collected largely from the same beds and their equivalents in other parts of the Malvern Hills, and they have since and before been examined by other geologists; so that in this case it was not necessary to fix the position of beds so well known. The same shell-beds are known to occur in other parts of the Malvern Hills, at Oyster Hill, in Surveyor's Gully, at Hart's Coal-mine, and other places mentioned by Von Haast in his report of 1871. Being the admitted equivalents of the black oyster beds at the Waipara and in the Trelissick Basin, and certainly of some part of the Amuri Bluff section, the collections by Von Haast from these beds in the Malvern Hills include too many generic and specific resemblances to forms found in the Tertiary strata of

New Zealand, and such an absence of truly Secondary forms that, admitting the stratigraphical determination of their equivalence to be correct, it seemed most desirable that some explanation of the suppression of the Secondary forms should be arrived at, and it was also thought that here might be found some indication of the reasons why there are yet fewer Secondary forms in the same or nearly equivalent beds overlying the coal strata of South Canterbury and north-eastern Otago.

Moeraki and Hawksbury Survey Districts. — The principal work of the season in this district was to ascertain if there is any probability of finding coal at moderate and workable depths in the vicinity of Palmerston; and at the very outset had to be determined the question whether or not the coal-bearing series of Shag Point belongs to the Cretaceo-tertiary formation. This being proved beyond reasonable doubt, would at once simplify the matter in dealing with the district around Palmerston, and would also finally determine a large area to the south and south-west as having present the rocks of the true coal formation of New Zealand. As the determinations of the Geological Survey in this respect have been questioned, and it has been maintained that the strata forming the floor of the lower part of Shag Valley and thence extending south and south-west to the neighbourhood of Dunedin and Saddle Hill do not truly belong to the Cretaceo-tertiary coal formation, but to a younger and a Tertiary formation, for this reason the entire district had to be carefully examined, and especially was it requisite that an explanation of the apparent unconformity along the south-west course of the Horse Range should be found. It was necessary to solve this difficulty before attempting to prove the age of the rocks in the neighbourhood of Palmerston, as it involved the possible presence or absence of coal-seams underlying a large area of eastern Otago.

The previous views expressed and put forward on this very important subject may be shortly detailed as follow:—

Determinations by the Director.—In 1864 I determined the succession of the beds in this age in the Oamaru, Moeraki, Waitaki, and Shag Point districts, as follows:—

1. Oamaru or calcareo-arenaceous series.
2. Moeraki or argillaceous series.
3. Waitaki. Arenaceous.
4. Carbonaceous series. Estuarine beds with conglomerates, sandstones, shales, and brown coal of fine quality.

Previously, in 1862, I had incidentally indicated the mode of their formation, and the succession of the beds as in the above classification, in a paper on the geology of the Manuherikia Valley.

On the 12th June, 1872, Sir J. von Haast reported on the Shag Point coalfields, and again contributed a paper on the same subject on the 21st February, 1873, and in these he points out that the rocks forming the greater part of the Horse Range and the higher southern part of Mount Vulcan, to the mouth of the Shag River, and thence along the coast to the Shag Point Coal-mine, constitute the series of rocks associated with the seams of coal worked at Shag Point, and are distinct from and unconformably underlie another series, having a similar lithological character in its lower beds and also seams of coal, but which is of much younger age and of Older Tertiary date, with which he associates the Katiki Beach septaria (? concretionary) beds, &c., the greensands and clays of Moeraki Peninsula and Hampden Beach. He describes a younger formation present along the coast-line south of the mouth of Shag River as "Middle Tertiary," and as yet younger the beds forming the floor of Shag Valley to the southern end of Blue Mountain Range and in the vicinity of Palmerston, as being probably lacustrine, perhaps of estuarine origin. In this way the extent of the Shag Point coal-measures is shown to be very limited, and as not being present in the vicinity of Palmerston.

In 1875 ("Geology of Otago") Captain Hutton described the Waipara formation (of which the Shag Point series is a part) as being "very feebly represented in Otago," occurring only in two localities, "the one of which is situate at the mouth of the Shag River and in the Horse Range, and extends in a northerly direction to the south branch of the Otepopo River." He states that the higher beds of the coal formation are sandstones and sandy clays, with almost spherical ferruginous concretions, which have been mistaken for septaria, and confused with the true septaria of Moeraki, which belong to a much younger formation (?). In the same report Captain Hutton describes the rocks of Shag Valley around Palmerston and thence to Waikouaiti as belonging to the Oamaru and Pareora formations of that report, and thus restricts the occurrence of the Shag Point coal-measures to the country on the north-east side of Shag Valley.

In 1877 Mr. Cox, late Assistant Geologist, examined the

rocks at Shag Point and along the north-east side of Shag Valley, some ten miles above Palmerston, and referred the whole to the Cretaceo-tertiary formation, pointing out that the apparent unconformity along the south-west base of the Horse Range was due to faulting of the strata on a large scale, and that the beds occupying the lower part of Shag Valley and around Palmerston belonged to the same period as the Shag Point coal-measures—a fact that has not been sufficiently recognised in subsequent writings dealing with the extent and age of the formation to which the Shag Point series belongs.

The question being in this condition when I examined the vicinity of Palmerston last year, although it was quite manifest that thin seams of coal did exist, in the absence of stratigraphical connection and palæontological proof, with the balance of testimony favouring an adverse decision that such coal-strata belonged to the Shag Point series, it was found that a further survey was required of the Shag Point and Horse Range district for the evidence requisite to determine the matter at issue, since, could it be shown that these Palmerston beds did in reality belong to the true coal-bearing rocks of New Zealand, a more constant development and a better quality of coal than the surface outcrops appeared to indicate might be expected.

Having this in view, the necessary work was commenced at Shag Point with the view of determining the relation of the upper grits and limonitic sandstone to the coal-beds there and the lower grits exposed along the north side of Shag Estuary, and forming the southern part of Mount Vulcan. The results proved that everywhere the succession of beds from the higher coal-seam shows that the same well-rolled quartz-grits overlying the immediate cover of the coal pass upwards into light-grey sands and sandstones weathering brown (limonitic sandstone), followed by grey sandy beds with concretions that pass upwards into the dark sandy and more argillaceous beds of Shag Point Railway junction and Katiki Beach, which are often gypseous in character, and contain vast numbers of spherical and irregular-shaped concretions of all sizes that externally are of a brown colour, but when broken into are of a dark bluish-grey. The coal is everywhere found at the base of this part of the series, and is manifestly conformable thereto, so that, in spite of some difficulties in the reading of the section along the southern base of Mount Vulcan, the conclusion arrived at was that there is but

one *formation* present, although for convenience of description it may be divided into two or more series or sets of beds. By means of the clearly-marked outcrops of the three permanent divisions of the lower part of the upper series, and outcrops of coal at various places, Mr. McKay satisfied himself that the upper part of the lower series containing the seams of coal worked or known to exist within the Shag Point coal lease encircles the central part of Mount Vulcan on three sides, reaching from the Shag River round the western and northern slopes of Mount Vulcan to the present coal-mine, and probably along the coast-line to near the mouth of the river. Proofs of the correctness of this stratigraphical determination being required, and necessary to its satisfactory demonstration, they were industriously sought for, and fortunately obtained.

The fossil flora of the coal-measures had already been largely collected during former surveys of the district, and its character determined and compared with that from other coalfields of New Zealand, but hitherto there had not been sufficient and satisfactory palæontological proof of the age of the series overlying the coal,—at least of the lower portion as developed near Shag Point. In the first catalogue of the Colonial Museum, issued in August, 1870, at page 194 three species of fossil shells are noted as coming from "clays with ironstone concretions overlying the coal-seams." These are Cardium sp., Cyprina sp., and Inoceramus sp. However, when Sir J. von Haast examined the district in 1872, in his preliminary report he said, "It seems to be, if not altogether devoid of the remains of animal life, exceedingly poor in them, as I could not find the least traces, notwithstanding the most careful search" (Geological Reports, 1871–72, p. 151); and again of the higher beds he says, "I was unable to discover any fossils in these beds, and also an examination of the septaria (the so-called Moeraki boulders) did not give any results" (Geological Reports, 1873–74, p. 25).

After having examined the district during the summer of 1873–74, Professor Hutton says: "Fossils are scarce in these rocks, but several casts of bivalve shells have been obtained from the upper beds. . . . . There is also in the Otago Museum a fragment of an ammonite which is said to have come from this locality."—("Geology of Otago," Dunedin, 1875, p. 45.) Neither did Mr. Cox succeed better when he examined the Lower Shag Valley district in 1882, so that there seemed little hope that the

palæontological proof so much needed would be obtained; but it has now proved otherwise, as Mr. McKay this last season obtained a large collection of fossil Mollusca closely related to, and in many cases identical with, those obtained from beds occupying the same position, as regards the coal, in the Malvern Hills.

Neither collection has as yet been sufficiently examined to institute a strict comparison of all the forms contained in each; but from a cursory glance it is sufficiently evident that we are dealing with fossils coming from beds belonging to the same geological horizon.

In Trotter's Creek, on the north-east slope of the Horse Range, the limonitic sandstone proved of importance in tracing the relations of the underlying coal-measures. Omitting the sinuosities of its outcrop immediately northward of Terapupu Creek, this well-marked stratum was traced to the lower part of the gorge of Trotter's Creek, where it is seen to underlie the Katiki Beach boulder-beds, and to overlie the upper grits. At the latter place it rises to a considerable height, forming high cliffs on both banks of the creek; and, although not at this place fossiliferous, it is easily recognisable by its peculiar character and position in relation to the Katiki boulder-beds.

From beneath the upper grits the horizon of the Shag Point coal-seam makes its appearance at the point where the line of road leaves Trotter's Creek; and the stream, turning to the north-west, passes through a deep gorge cut through the lower beds of the coal-bearing series, which are here about 1,000ft. to 1,200ft. thick, and not coal-bearing, but mainly formed of rough subangular material.

Katiki Beach and Lower Part of Trotter's Creek.—The western side of the syncline between Mount Vulcan and Puke Iwitai continued to the north forms the north-east slope of the Horse Range; and the downs along the coast-line as far as the mouth of Terapupu Creek are formed of Katiki Beach boulder-beds. Beyond this creek the beds trend more to the north-west, and follow the limonitic sandstone through the hilly country to where the main road going north to Oamaru crosses it for the last time. On the line of road the Katiki Beach boulder-beds are not exposed; but the sweep of the entire succession of beds from the very base of the upper series and the Shag Point coal itself from near the coast-line north-west to the gorge of Trotter's Creek explains the difficulty, and shows that there is no real

unconformity, and that we still have to do with higher beds belonging to the Cretaceo-tertiary formation as surely as the Shag Point coal-measures or the lowest beds of the entire sequence seen in the Horse Range belong to that formation.

Hence the determination of the true position of these greensands is not merely an interesting element in the stratigraphy of the district, complicated as it is by knotty points in the palæontological relations of its fauna, but it is of the greatest importance and closest bearing on the extension of the coal-bearing area farther to the north, and of no less consequence in its application to the district south of the Horse Range, Shag Valley, &c., around Palmerston.

It is important to note that in this part of the district Mr. McKay obtained from the concretions of Katiki Beach several specimens of saurian remains, consisting of vertebræ, humerus, and carpal bones, and reports that boulders containing bones are not rare, but that usually the bones are so ill preserved, and so thoroughly transformed into hollow casts, that their extraction in anything like a complete and intelligible state would require extensive excavations. These bones occur in strata some 200ft. to 300ft. above the shell-beds at Shag Point and on the eastern slope of Puke Iwitai.

Moeraki Peninsula and Hampden Beach.—This part of the district was examined for the purpose of ascertaining if the beds there present belonged to the higher part of the coal-bearing sequence, or to a younger formation conformably overlying; this latter relationship having been maintained by Sir J. von Haast and Professor Hutton, the latter believing the beds containing the celebrated Moeraki boulders and the fossiliferous beds of Moeraki Peninsula and Hampden Beach to be of Miocene age.

No unconformity was detected between these beds and the greensands overlying the Katiki Beach beds, on which they rest. At the northern end of the Hampden Beach the fossiliferous beds which overlie the Moeraki boulder-beds are seen to underlie the volcanic breccias and tufas forming the hills south of the mouth of the Otepopo River, which in their turn can be traced to the Oamaru building-stone at Kakanui Mouth, and at Maheno four miles farther up the river, thus completing the succession from the lowest to all but the highest beds of the Cretaceo-tertiary sequence, the Grey-marls not being proved present.

The important inference is that there are not two coal-bearing

formations in the district lying along the seaboard north-east of the Horse Range, but that the various coal outcrops near the base of the sequence from Big Hill and the vicinity of Oamaru to Shag Point are all of the same age. In the same manner also it has been shown that future careful surveys may, with close approximation to the actual depth, indicate the amount of sinking required to reach the coal at any point between the places named, which could not be done if the coal sequence were unconformably overlain and its upper members hidden by a younger formation.

Lower Shag Valley south-east of the Main North Road.—Previous to 1881, in reporting the results of their surveys, Sir J. von Haast and Professor Hutton had expressed decided opinions as to the unconformable relation of the beds forming the floor of this part of Shag Valley to the rocks of the Horse Range and the coal-bearing series of Shag Point, and both describe a double series of Tertiary beds, unconformable to each other, as being present here and in the district immediately to the south. In 1882 Mr. Cox examined the lower part of Shag Valley as far as Waihemo, and, in reporting the results of his work, arrived at a different conclusion and, as already stated, referred the rocks of the low grounds of this part of Shag Valley north of the river to the higher part of the Cretaceo-tertiary formation, and considered that these being in contact with the lower series, and apparently unconformable thereto, was the result of faulting along the south-western base of the Horse Range; and he says, "It is therefore very probable that a great extension of the coal-bearing formation occurs below the Palmerston Flat" (Geological Reports, 1882, p. 56).

Mr. McKay, having ascertained that from the north-east side of the Horse Range to the sea the thickness of the strata overlying the coal could not, save perhaps at the mouth of Trotter's Creek, be more than 1,000ft., had therefore to consider that the other 5,000ft. to 6,000ft. required to make up Professor Hutton's estimate of the thickness of the whole formation must be formed wholly of the grits and conglomerates of the Horse Range, which underlie the Shag Point coal. There is, however, no appearance of such a great thickness of conglomerates at the base of the series on the south-west side of the fault-line indicated by Mr. Cox—a fact which appeared to favour the theory opposed to that held by Mr. Cox. An examination of

the Horse Range, however, showed that the thickness of the grits had been greatly over-estimated, and that probably these were not more than 1,200ft. to 1,500ft. thick, and considerably thickest towards the south-east end of the range. This at once paved the way for the acceptance of the fault-theory, but the identity of the higher beds on both sides of the range had to be proved. Fortunately, apart from mere lithological resemblances, means of doing this were discovered. The limonitic sandstone, full of the same fossils as those found on the eastern slope of Puke Iwitai, was found in the isolated hill close to Rich's woolshed, a quarter of a mile below where the Oamaru Road begins to ascend the Horse Range, and rested on the grits associated with thin seams of coal (Shag Point coal?). These grits, with underlying conglomerates, appeared continuous with those forming the lowest beds of the series on the higher part of the Horse Range, and extended along the road in the direction of Palmerston until abruptly terminated by what appeared to be a second line of fault. Followed to the south-east along the line of Woolshed Creek these and the succeeding beds were found arranged as a syncline narrow and raised towards the north-west, but on one side, the south-west side, rapidly widening as the higher following beds appeared to the south-east; and by the time the swampy land bordering the upper part of the Shag estuary is reached, the entire succession up to the calcareous rocks representing the Ototara limestone (Oamaru building-stone) has, bed by bed, made its appearance.

Thus, against the grits of the Horse Range successively abut the limonitic sandstone, Katiki Beach boulder-beds, greensands, dark sandy clays weathering to light bluish-grey (Hampden Beach beds), and south-east of Puke Iwitai the higher calcareous members of the series as seen in Puketapu and Mount Royal, near Palmerston.

This being the same sequence of beds that conformably overlies the coal on the north-east side of the Horse Range, the lower beds of which sequence form the crest of the southern end of the range, and the whole series having fully participated in all the movements and upheavals which have brought the rocks of the series underlying the Shag Point coal into their present position and structural arrangement, it follows that the same strata recur on the south-west side of the range, in exactly their original relationship.

Consequently, if the facts are as here stated, Mr. Cox's theory of the beds on the south-west of the Horse Range being brought into their present position and apparent relationship by faulting must be the correct one.

The southern side of the lower part of Shag Valley showing only alluvium deposited by the river within recent times, no direct connection could be shown between the rocks of the area under consideration and those of the same age surrounding the Township of Palmerston; but each particular set of beds was traced in this direction as far as possible. The higher beds so followed continued until they disappeared under the alluvial flat on the north side of the river. The limonitic sandstone in part, and the whole of the underlying beds, terminate abruptly before reaching the edge of the downs, and, as along the south-west base of the Horse Range, by faulting.

Mr. McKay is of opinion that the fault along the south-west base of the Horse Range dies out as it is followed to the north-west, and effects but a small displacement of the strata beyond where it is crossed by the Main North Road. This would be difficult to trace after passing on to the area formed by the older rocks, but, as affecting the Cretaceo-tertiary rocks, it appears certain that the displacement increases as it is followed down the valley of Woolshed Creek, and is greatest on the coast-line at the mouth of Shag River.

The rocks in the vicinity of Palmerston were described last year in a report dealing with the prospects of coal in that district, and from the foregoing it will be apparent that, whatever may be the actual probability of finding workable coal-seams near Palmerston, the rocks of the Shag Point coal-measures are present, and are represented by the first 300ft. of strata forming the base of the Cretaceo-tertiary series.

The greensands showing in the railway-cuttings at Palmerston Railway-station, and thence at various places along the line for some distance down Pleasant Valley, are, apart from being an indication of the presence of coal-bearing rocks underlying them, of considerable economic importance, as they contain large quantities of valuable iron ore. A sample of this, taken during the course of this survey from the deep railway-cutting opposite Mr. Douglas's station (Mount Royal), although apparently consisting of little else than greensand, yielded on analysis 37 per cent. of spathic iron ore. As elliptic masses of this ore 1ft. to

3ft. in diameter occur in great abundance, it could no doubt be profitably mined.

Allusion has been made to the relation of the Shag Point beds in the Pleasant River area. The identity of the lower beds with those at Shag Point may be shown in another and scarcely less satisfactory manner, viz., by following the sequence along the valley of Woolshed Creek to the Shag River at the upper end of its estuary, where the calcareous sandstone representing the Oamaru building-stone is well developed, forming the low downs between McLeod's swamp and the river, along the bank of which a clear section is exposed. There the calcareous sandstone abuts against the limonitic sandstone and Katiki Beach beds on the north-east side of the fault, passing the southern base of Puke Iwitai, and appears on the opposite side of the valley with such strikes and dips as to warrant the inference that between the two exposures the beds in question are continuous under the river-flat.

Westward from Bushy Park house the calcareous sandstone, which is of very considerable thickness, forms the western slopes of the coastward hills, and the eastward slopes and higher parts of Puketapu up to 800ft., after which the top of this mountain is formed of basalt. The rocks of the western slope of Puketapu, underneath the calcareous sandstone, are marly, light-coloured chalky clays, which contain a few fossils connecting them with the rocks of Janet's Peak, &c. Underneath this is a soft light-grey micaceous sandstone, forming the base of Puketapu and the northern lower slopes of Mount Royal. These beds are, to some extent, developed within the borough of Palmerston, and are underlain by the dark greensands containing concretions of spathic iron-ore. As from the upper surface of the calcareous sandstone all the beds are strictly conformable to those on which they rest, the beds from the highest (the calcareous sandstone) to the lowest (the shales and grits of the coal-bearing series) of the sequence are necessarily parts of one and the same formation, and the strict equivalents of the beds on the south-west side of the fault along Woolshed Creek and the lower slopes of the Horse Range, which lithology, stratigraphy, and palæontology alike, prove the same sequence as that seen at Shag Point, and include all but the very lowest rocks of the Horse Range itself.

Along the western boundary of this district the railway closely

follows the strike of the beds, exposing near Palmerston the upper part of the greensands, and near Waikouaiti the clays immediately under the calcareous sandstone. At all points along this line the section east to the sea shows the same succession of sedimentary beds, dipping at low angles to the eastward.

Without question the greensands and coal-bearing rocks are present under the calcareous sandstone, developed to a great extent within this area; but, as a rule, the coal-seams (even if workable) must lie at depths varying from 1,200ft. to 1,700ft. below the present surface, so that they are practically out of reach at the present time.

The calcareous sandstone in Puketapu and Mount Royal, and at Tumai on the south side of Pleasant River, contains about 75 per cent. of lime, and is therefore available for the ordinary purposes for which lime is required, and should be of value to the agriculturist.

Upwards it passes into a calcareous rock, wholly composed of Foraminifera and exceedingly minute acicular bodies not yet determined. This rock is the highest of the Cretaceo-tertiary sequence in this part of the Otago District, and may be regarded as representing the Grey-marls in other parts of New Zealand.

The Tertiary rocks begin with a rubbly shelly band resting on the upper surface of the rock last mentioned, and, as grey sands with bands and concretionary masses of a more calcareous character, extend continuously along the coast-line, reaching inland from half a mile to a mile, and in one case, where there is some appearance of unconformity, to a distance somewhat greater.

At Bobby's Head, between Goodwood and Bushy Park, volcanic rocks appear on the coast-line, consisting of solid basalts and porphyritic dolerites, associated with trachytic breccias that much resemble the rock of this character quarried at Port Chalmers. Mr. McKay thinks that this outburst is of date subsequent to the deposition of the Tertiary beds of the same district, as the solid rocks appear to have burst through the dark sandy beds of that age in the vicinity. This, indeed, may be the case, and yet the breccia-beds of the nature of the Port Chalmers stone may be of much older date, it having been shown that felsitic trachytes and accompanying breccias derived therefrom, which have the microscopic structure of true propylites, lie at the base of the coal-bearing series on one side of the fault-line running along the north-east side of Shag Valley (Fault No. 2, not that

described by Mr. Cox). However, that there was an outburst of volcanic rocks during Miocene or Post-miocene times is tolerably certain; and that to this period belong the basalt caps forming the higher parts of Mount Royal, Puketapu, Smyler's and Janet's Peaks, Taieri Peak, Mount Pleasant, Middle Mountain, Mount Trotter, Mount Mackenzie, Mount Watkins, &c., is scarcely to be doubted, as the basaltic sheet that once was continuous over the district rested, as the portions yet remaining testify, on almost every member of the Cretaceo-tertiary sequence.

Excepting the low grounds of Flag Swamp and the adjoining hill-slopes to the south, and a narrow belt along the western side of Pleasant Valley, the greater area of the district west of the railway to Mount Watkins and Taieri Peak is formed of conglomerates, grits, and sandstones, with beds of shale, and at places thin coal-seams overlain by limonitic sandstone and greensands. A considerable extent of the area, however, exposes schistose rocks at the surface, more especially within the watershed west of Mount Pleasant. It is over this part of the country that coal-outcrops should be seen were coal-seams developed to any great extent, but, except in Mount Pleasant and some of the gullies to the northward of the known coal-outcrop on its eastern slopes, no exposures are known.

Nevertheless it must be borne in mind that in every case the coal thickens as the seams are followed to the eastward into deeper ground, the dip of the strata being in most cases in that direction, and that the farther west the outcrops are found overlapping the schists the less important in all probability they will appear to be. Thus, lying above the schists forming the base of Mount Watkins there is about 200ft. of coal-bearing and other strata before the basalt cap, forming the higher part of the mountain, is reached. More to the north-west the table-land east of the Stone Burn, on which Mr. Orbell's woolshed stands, shows only a trace, the last remnants of the lower grits at a height of 1,200ft. above the sea; but on the opposite side of Stone Burn the same beds have been preserved intact, and, occurring at a lower level by some 200ft. or 300ft., are, before being covered by the basaltic cap, overlain by greensands. Probably underlain by limonitic sandstone, a 4ft. seam of coal is known to exist, but is too distant and difficult to reach to be of any value to settlers in the vicinity of the railway-line, who can be

supplied more cheaply from Shag Point or even Kaitangata than they could be from this seam under present circumstances.

It having been reported that a thick seam of coal was exposed during the progress of some alluvial gold-working at the upper end of the first schist gorge of Shag Valley (Glover's), this locality was examined by Mr. McKay, and the following account is condensed from his weekly progress report. Little could be seen, save that a quantity of quartz-gravel and some coaly shale had been brought to the surface, while the nearest rocks of the same age that could be seen *in situ* consisted of dirty gritty greensands with much fossil wood. As however at this place these rocks formed nearly the base of the series, it became of interest to ascertain what changes in their lithology and stratigraphical arrangement had taken place as they were followed farther up the valley, since it was evident that here the limonitic sandstone and Katiki Beach boulder-beds had been eliminated from the theoretical sequence and never been deposited, the greensands immediately succeeding the upper grits, the lower series also being absent. It was also necessary to ascertain the nature of the eastern boundary of the beds higher up the valley, and with these objects in view a special examination of this part of Shag Valley was undertaken. The fault-line was traced to the south-western base of the higher part of Blue Mountain Range, and the rocks making contact with the Palæozoic strata on the north-east side of the fault were ascertained to be the higher division of the greensands.

At the second schist gorge the lowest Cretaceo-tertiary rocks seen are intensely dark greensands exposed in the river-bed, where they are lying flat or dipping eastward at very low angles. Abreast of this point, and for some distance up and down the valley, the fault with all the Cretaceo-tertiary rocks to the west of it are obscured by Post-pliocene or Recent beds. On following the river upwards to within little more than a quarter of a mile of Dunback Railway-station its bed from the second gorge continued to be schist; but then a change took place, and the lower strata of the younger formation were exposed. As here seen the lowest beds consist of but a few feet of gritty and coarse sandstone, followed by greensands, which a little higher up the river contain calcareous and ferruginous concretions, sometimes full of fossils.

A quarter of a mile above Dunback shaly clays appear on

both banks of the river, which, at first sight, appeared to overlie the greensands already mentioned, but which farther up the river proved to rest on the schist rock, and thus form near Kitchener's station (the Grange) the base of the series. Following now the beds to the eastward, or in the direction of their dip, beds in character not unlike the Katiki Beach boulder-beds are seen to overlie, and these have in their higher part concretionary boulders sometimes full of fossils. Farther to the eastward the whole sequence, so far as yet stated, is overlain by rusty ferruginous greensands, with bands of fucoidal greensands, which continue to the eastward till cut off by the sheer of the great fault, which certainly continues for some distance farther up the valley beyond this point. In this line of section, therefore, it was evident there was but little chance of finding coal, so that, after tracing the fault-line some two miles farther up the valley, and making a collection of fossils from the boulders already noted, further examinations were not proceeded with.

South of Waikouaiti to Dunedin the continuous development of the Cretaceo-tertiary rocks can be easily observed as far as Blueskin. The calcareous sandstones of Puketapu, Mount Royal, and thence following the railway-line to Waikouaiti, south of Waikouaiti Bay, are continued along the sea-coast as far as Merton.

From underneath these, on the inland side, light-coloured marly clays and greensands occupying an inferior position are seen to crop out at many places, and without doubt farther to the west the coal rocks would also appear were it not that they are covered by the volcanic rocks forming the higher part of the coast-range. As it is, the schist rocks, reaching well down the valley of Kilmog Creek, nearer Blueskin, expose lower beds than the greensands themselves, and sandstones with fossil wood have for many years been known on the hill-slopes at the back of Blueskin.

For some distance up the Waitata valley only volcanic rocks can be observed; but for a mile or more before reaching the bridge crossing the stream for the last time calcareous sandstone has been cut through in making the road-cuttings. This is the same as that reaching from Palmerston to Merton, and which is seen yet higher up the Waitata, overlying oil-shales, in the vicinity of which a seam of coal has lately been discovered.

Following the newly-made road-line down the valley of the

Water of Leith, no sedimentary rocks are exposed; but it is well known that on the opposite slope of Flagstaff Hill along both sides of the valley of Silverstream the grits and sands of the Green Island and Saddle Hill coal series have a full development. Farther to the south, at Brighton, the coal-bearing series is thin, compared with what it is at Green Island; but nevertheless there is a fair workable seam of coal on the south-east slope of Saddle Hill, which was at one time opened out to some extent, but the coal has for some time been disused, and the works are at present at a standstill. Lower down the hill, near the level of the beach, some prospecting has lately been done on Mr. Graham's land; but the seam exposed is thin, and, unless underlain by a thicker seam, the measures here are not of much importance. They dip, however, at low angles, and are otherwise favourable to the working of any coal that may be found at or above sea-level.

The grits, sands, and clays forming the proper coal-measures are here overlain by limonitic sandstone and a gritty calcareous rock full of shell-fragments that almost without exception belong to a species of oyster that cannot be distinguished from the black oyster of the Malvern Hills coal-beds, in Canterbury. In the same beds occur numerous fusiform bodies, respecting the zoological affinities of which there has long been a difference of opinion—viz., whether they should be referred to the Belemnitidæ, or simply considered Cidaris spines changed to aragonite and thus acquiring a fibrous radiate structure. Fortunately, among a considerable series of these fossils collected by Mr. McKay on this occasion, there prove to be at least two specimens showing distinct traces of an alveolar cavity (no phragmacone being present); and there is also another specimen preserving the upper part of the guard sufficiently well to show that originally there was a ventral groove or fissure, the lower part of which can be traced in the shell-structure. This would indicate that this fossil is a species of Belemnitella, and not a true Belemnite.

This fossiliferous bed is overlain by dark-grey sand, in turn succeeded by greensand capped by the volcanic rocks, Saddle Hill and Stony Hill.

Following the coal formation still farther to the south, the district east of Taieri Plain and Waihola Lake was re-examined by Mr. McKay, but only with reference to certain coarse angular breccia-beds, apparently of glacier origin, the age of which has

never yet been clearly determined. In the large-scale MS. geological map of Otago which I made in 1864, I plotted in this conglomerate as an outlier of the alluvial deposits of the interior basins or plains of Otago. Professor Hutton describes it as an "immense accumulation of clay and angular blocks of schist of all sizes that is found on the eastern side of the Taieri Plain, extending from the Taieri River nearly to Otakaia, a distance of about three miles" ("Geology of Otago," p. 62).

This deposit he further supposed to have accumulated in the interval that elapsed between the Pareora and Wanganui formations, and to be referable to the Older Pliocene period.

Mr. McKay examined this deposit, and followed it to its north-east limit in the direction of Brighton; he ascertained also that its present arrangement is as a syncline, and that the beds rest upon the lower grits of the coal-bearing series which flank it on either side, coal having been found a little to the eastward of Otakaia, and again two to three miles east of Henley, a mile or so north of the Taieri Bridge, on the Main South Road; but here there was no evidence tending to show what is the actual age of the deposit. At the back of Henley the deposit is composed of exceedingly angular material, often containing blocks of great size, 5ft. to 10ft. or 12ft. in diameter, and is but loosely compacted together, the irregular spaces between the confusedly-heaped angular blocks being often filled in with finer material. This is the character of the higher beds. The lower beds in this neighbourhood are formed of finer materials, and associated with red unctuous clays, regarded in the district as a possible source of hæmatite paint. Near the Taieri Bridge, on the north side of the river, the lower beds resting on the schist are solid compact breccias; and on the opposite side of the river, followed in the direction of the Waihola Railway-station, they are not of a very coarse description; but east of the railway-line, where the beds form hills 500ft. to 300ft. in height, immense angular blocks are again seen to be present.

Close to the Waihola Railway-station Mr. McKay reports that these beds are well exposed in the railway-cuttings, and are but moderately coarse, and clearly stratified with beds of sand and silt, dipping to S.E. at moderate angles up to 30°.

These sands within the township have been invaded by volcanic rocks, appearing as massive dykes 4ft. to 15ft. across, altering and indurating the sands and clays considerably, and within the

upper township breaking through the lower beds of the coarser upper part of the formation.

From the railway-station followed to the eastward the more characteristic higher and coarser beds continue in a direct line for about three miles towards the coast-line, and rise into hills 800ft. in height. In this direction the dip of the lower beds changes to N.W., and the material forming the beds of the whole eastern outcrop is often sandy, and, when of coarser material, often well rounded.

So far as could be observed, the material forming the beds corresponds to the character of the schistose and altered Palæozoic rocks of the near vicinity. Tracing these rocks yet farther to the south-west they were found to have an immense development between the section-line last described and immediately east of Waihola Gorge, east of which the latter as the characteristic coarser beds are 800ft. thick, and in Trig. Hill, overlooking the Tokomariro Plain, attain an elevation of 1,200ft. above sea-level.

It will be thus seen that, according to Mr. McKay, the beds are of much greater extent and thickness than as heretofore described, and that the lower beds, at least, have been deposited prior to the latest manifestations of volcanic energy within the Otago District. Whether their age is Miocene or Eocene has yet to be determined: possibly it may prove that the period of their deposition was not greatly different from that during which the upper sandstone conglomerates of the Clutha (Kaitangata) Coalfield were formd.

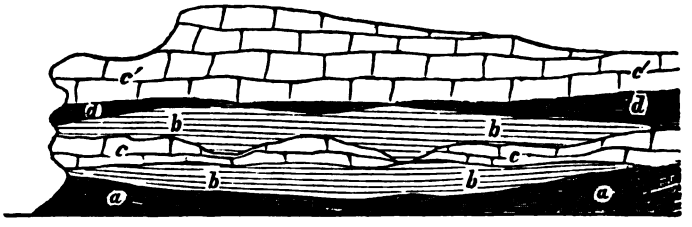
No trace of these beds could be discovered in contact with or underlying the limestones of Waihola Gorge; and west of Waihola Lake and the depression bending south to Waihola Gorge they are found only in the low flat part of the peninsula opposite the railway-station and township of Waihola.

In his field notes Mr. McKay suggests the possibility that this conglomerate may be a local equivalent of the great Post-miocene conglomerate which is described in the last volume of Reports as being such an important feature in the Kaikoura district.

McRae's Flat.—Mr. McKay paid a visit to this locality for the purpose of examining the mode of occurrence and character of the Duke of Edinburgh Reef; but found that very little was to be observed, as the reef was nowhere to be seen. No work

appears to have been done on the Duke of Edinburgh Reef since it was visited by Professor Ulrich eleven years ago, and, as he had to depend mainly on the account given by Mr. A. Simpson, this is all that remains to us, seeing that none of the old shafts or workings now show the reef; and, with the exception of some specimens of the quartz and country rock which were collected by Mr. McKay, no further work could be done. The sample of quartz taken from a stray block lying in the open-cast working has been analysed, and yielded at the rate of 2oz. 5dwt. to the ton. A sample of the mullock showing on the track of the reef where some work has been done in the gully eastward from the battery-site gave only traces of gold.

Kakanui Mouth and Allday Bay.—In continuation of former examinations two days were spent in this district, during which a large collection of fossils was made, and the relation of the different formations present determined. He also made a collection of fossils from the marly strata in part the equivalent of and in part underlying the Ototara stone on the left bank of the Kakanui River, opposite Maheno, referred to in the following section :—



Maheno, north bank of Kakanui River. *a*. Waireka tufas. *b*. Marls (= Amuri limestone). *c*. Ototara stone, interbedded. *c'*. Ototara stone, overlying. *d*. Upper tufas.

The Lower Greensand and Cretaceo-tertiary Formations (Cretaceous system of rocks), the true and almost only coal-bearing formations of New Zealand.—It is no doubt true that there are valuable deposits of fossil fuel occurring in various parts of the colony that have been variously referred to different geological periods during the past history of the geological survey, and the age of which is not yet satisfactorily determined. Some of these are now known to be of younger date than the Cretaceo-tertiary period—viz., various deposits of lignite in the Wellington District of the North Island, and possible occurrences of the same material in the Nelson and Westland Districts of the

west coast of the South Island; also a deposit of the same nature found on Castlehill Station in the Trelissick Basin, Canterbury, and a bed of lignite overlying the marine beds of Miocene age within the watershed of the Upper Pareora, South Canterbury.

More doubtfully to the same period must be referred the lignites or inferior brown coals of the Hakateramea and Waitaki Valleys, forty-five to fifty miles inland from Oamaru.

There are also the thick deposits of fossil fuel occupying or found within the interior lake-basins of central Otago, which have been generally referred to the Tertiary, sometimes to the Late Tertiary period; but the evidence is by no means clear that all the known occurrences of such should be so referred. Again, there are, farther to the south, in the Taieri, Clutha, and Mataura valleys, various and sometimes very thick deposits, in some places a mere lignite, at others a second- or third-rate brown coal, that are usually considered as belonging to the Miocene period, but which, in more than one instance, will in the future have to be placed in the Cretaceo-tertiary formation. There is even now no decisive evidence that the Mataura lignite near the railway-line opposite the township of that name is not of Cretaceo-tertiary date, and it is certain, from the abundance of ambrite (derived from a coniferous tree closely allied to the kauri of the North Island, but which has long since disappeared from the South Island) occurring in this deposit, that the vegetable matter composing it differed but little from that which formed the coal-seams of Green Island and Shag Point. The same remarks will apply, and with even greater force, to the country north-west of Mataura, and flanking the Hokonui Hills within the watershed of Makarewa Stream.

Exceedingly modern-looking deposits of lignite are found along the eastern shore of New Harbour, between Invercargill and the Bluff, but the very modern date which has been assigned to these deposits rests on no further authority than the but slightly compressed condition (comparatively speaking) and inferior quality of the lignite.

The brown-coal formation farther to the north-west at the Nightcaps, Morley Creek, and Centre Hill, there can scarcely be any question, belongs to the Cretaceo-tertiary period; but there are further deposits more to the west, and on the coast-line towards Riverton and Orepuki, respecting the age of which there may justly be a difference of opinion, as the geology of this

district has not been worked out in the light of recent discoveries.

But, besides in these localities named, it has been contended that the North Island coals wholly, and those of Nelson and the west coast of the South Island in part (excepting the bituminous coals), together with all the coals of the East Coast saving those found in the Malvern Hills (Canterbury), at Shag Point (Otago), and at Mount Hamilton (in the Southland District), should all be referred, not to the Secondary epoch, nor to a Cretaceo-tertiary formation, but to some part of the Tertiary period.

Practically, it matters not whether we consider our coalfields to be Tertiary or Cretaceous as regards the period when the coal-seams were deposited; but it is of the very greatest importance whether they belong to one or two or more periods, and it is this that, under guise of a controversy as to the age and nomenclature of the beds, is the point at issue, and it is to prove the identity of the principal coal formations of the colony that the Geological Survey has laboured during the past fifteen years. Indeed, as far as my own views on the subject are concerned, they have ever been what they are now—that we must regard all the great coal-deposits of New Zealand as belonging to one sequence of strata, or otherwise involve any systematic consideration of them in inextricable difficulty.

As a successful effort to prove the unity of the coal formations of Canterbury and eastern Otago, the good work done by Mr. McKay during the past season, the principal facts of which have been thus stated, speaks for itself.

During the remainder of the period referred to in this report Mr. McKay has been engaged in the survey of the north part of the Hawke's Bay District, including the mountain country between Waikare-moana Lake and Fort Galatea and the coastal district, which includes Mahia Peninsula. He then crossed the Urewera Range from Waikare-moana, this being the first time this part of the country has been examined. He also visited the Tarawera district, and collected a large series of rock-specimens from the site of the volcanic disturbance of June, 1886, which are now being submitted to chemical and microscopic examination. (For convenience of reference, my own report on that eruption, dated the 23rd June, 1886, has been reprinted in this volume from the Parliamentary

papers.) The survey of the district inland from the East Cape, including the Hikurangi Mountains, was also continued, with a view to determine the relations of the bituminous shales and oil-bearing series of the Waiapu Valley. The details of the structure of the East Coast district of the North Island are still imperfectly known. Along the east flank of the great anticlinal of which the Tararua, Ruahine, and Kaimanawa mountains are the core, the Lower Secondary rocks, which are so conspicuously developed on the west side of the North Island at Kawhia, appear to be altogether wanting, as I am inclined to remove the plant-bearing sandstones of the Whakarara Range from the Mataura to the Kaihiku series. On the other hand, we have an outcrop commencing on the East Coast south of the Akiteo River of a great formation that, from its fossils and relations to overlying rocks, would seem to constitute a passage-formation, embracing the Mataura (Upper Jurassic) and the Amuri (Lower Greensand) series. This formation increases in importance as a feature in the geological structure of the country as we pass north towards the East Cape until, in the Hikurangi Mountains, it acquires its greatest development, and forms the lofty ranges and peaks in which the Waiapu takes its rise. The upper part of the formation is that which carries the oil-shales, and passes conformably, in the same manner as at the Amuri Bluff, into the marine strata that belong to the Cretaceo-tertiary formation and in other parts of New Zealand form the cover of the coal-bearing strata.

During the season's work Mr. McKay collected much information respecting this interesting country, and forwarded to Wellington 25 cases containing 5,000 specimens of fossils and 150 rock-specimens characteristic of the different formations in the district examined.

In the district south of Napier several localities were examined either for the first time or to verify former observations. At Takapau, Waipukurau, and at Mount Vernon the relation of different Tertiary strata was reinvestigated, and their fossils were collected as a means of correlating the beds with other rocks of apparently the same or nearly the same age in the northern part of the Hawke's Bay District. A further examination of the Secondary rocks in the vicinity of Waipawa was made, and the notes taken proved of the greatest value in correlating the rocks of this district with similar rocks in the Poverty

Bay and East Cape district. The argillaceous limestones or highly calcareous chalk-marls of the district may, it would appear, be of consequence for the manufacture of Portland cement, a specimen of such chalk-marl having been analysed in the Colonial Laboratory which showed the presence of a full proportion of the alumina requisite in such a compound.

At Patangata, on the Tukituki River, freshwater beds of young Tertiary date were examined. These contain beds of lignite and clay iron-ore of excellent quality that render them of some importance, apart from which they are of great interest from a geological point of view.

On the East Coast, between Waimarama and Maungakuri, the volcanic rocks and manganese deposits of Red Island and the neighbouring mainland were examined, and the Cretaceous age of both was determined. The manganese ore occurs in some quantity, but the proposal to work it and send it to market has for the present been abandoned.

The gravels, pumice-sands, and lignite-beds on the south shore of Hawke's Bay were examined, also the same beds where they form downs to the east of the Township of Havelock, and the relations of the Tertiary and Cretaceous beds of the Lower Tukituki valley.

The different beds in Scinde Island were again examined, without the setting-aside of former conclusions respecting them. It may be noted that the excavations in connection with the formation of the breakwater on the north-east of the island have exposed soft grey sandstone (almost unconsolidated sands) under the lowest beds of the Scinde Island limestone. These sands appear 4ft. or 5ft. above the level of the breakwater, and, should it happen by the removal of the beach-shingle at the foot of the cliff that they become exposed to the action of the tide and heavy surf which breaks there, damage may result to the harbour works in process of construction. It may be that such a contingency will not arise; and the general opinion is that the protecting bank of shingle will be added to rather than diminished; but it would be well if the possibility of such an event were guarded against.

The geological formations forming the greater portion of Hawke's Bay District north of Napier were examined, but no metallic lodes or other deposits of exceptional value were discovered. Pumice-sands, as a superficial deposit, are found over

the whole district, and add nothing to the richness or fertility of the soils, but there are areas within which the comparative sterility of the soil is not wholly owing to the presence of this latest deposit of pumice-sand, but is due to the pumice contained in the stratified rocks from which the soils have been mainly derived.

The limestones of the district cover a considerable area, and form broken hilly country on the coast-line from Petane to Tiwhanui, three miles south of the Waikare River, and the whole of the higher part of the Maungaharuru Range, north-east of Titiokura saddle, and the Whaka Range to the south-west. Despite the presence of the superficial pumice, these limestone areas are good grass country. Between the two exposures of limestone the soil over a belt of country eight to ten miles in width is of an inferior description. Its greater sterility is due to the fact that the rocks abound in beds of pumice-sand and other arenaceous material, the poor soils derived from which have lost a little and gained nothing by the addition of the superficial pumice-deposits.

The Mohaka Valley, north-east of the Napier–Taupo Road, was examined. Coal-seams have been reported to occur in this part of the district, but the reports appear not to be well founded, or the coal occurs in such inaccessible positions as would make the working of it wholly unprofitable at the present time. Gold also, it is thought, occurs on the banks of the Mohaka, below the Waipunga junction, and in Stony Creek, which from the west joins the Waipunga near Tarawera. An examination of the rocks at these places was made, and from this it would appear that the prospects of finding gold are not different from what they appear to be in the Pohangina River, on the west side of the Ruahine Range, and throughout the Tararua Mountains in the Wellington District. Speaking of the prospects of such gold-mines, it is just possible that heavy bodies of quartz may be found containing such a percentage of gold as in favourable situations would make their working a matter of profit, but it unfortunately happens that none such have yet been found along the main range of the North Island.

Along the northern boundary of the Hawke's Bay District these older rocks are followed by Tertiary beds that continue to the eastward until the Nuhaka River is reached, beyond which Secondary rocks occur on the coast-line to the boundary of the

provincial district. Mineral springs occur in these rocks, some of which, not far from Mahia, contain a large percentage of iodine, and may otherwise prove to be valuable waters.

On Mahia Peninsula, near Table Cape, in Tertiary formation of considerable antiquity, thick beds of consolidated pumice-sand were discovered. This material is sufficiently indurated to form a good building-stone, and in its colour and fineness of grain is not second to any building-stone in the country.

From Clyde, at the mouth of the Wairoa River, the geological formations to Waikare-moana Lake were examined, and north-west of the lake the mountainous districts surrounding the sources of the Whakatane River were explored, and thence the country to Ahikereru and Galatea. Tertiary or Cretaceo-tertiary strata were found to extend from the westward quite across the eastern watershed, and for several miles into that of the Whakatane River. Farther to the north-west the rocks are Palæozoic sandstones and slates, except in the low grounds of the enclosed basin extending south-west from Ahikereru. Farther to the north-east the shore of the Bay of Plenty, from Opotiki to Cape Runaway, was examined, and, where possible, the country inland was also examined; but the only indications of the occurrence of metallic ores appear in the Promontory of Te Kaha, where copper ore was found, but not in paying quantities.

In the Waiapu Valley, where boring for petroleum oil has been carried on for some years, rocks belonging to the oil-bearing series are found over a considerable extent of country, and the formation to which they belong is of great thickness. The gas- and oil-escapes are for the most part confined to the middle series of the three into which the formation is divided, and the relative position of this to the others was examined with some care.

The Southern Cross Company have pierced this middle series to a depth of 1,700ft. without finding more than indications of oil, and intend putting the bore down another 300ft., in the hope that oil may be struck at or before reaching a depth of 2,000ft.

It has been supposed that a black bituminous shale outcropping on the coast at Awanui, Waipiro, &c., is the source of the oil and gas that reach the surface. This shows in the banks of the Tapuwaeroa River, and has long since been passed

through in the last of the bore-holes put down on the Rotokautuku lease, and the bore would now seem to be entering on a series of highly-disturbed and much-shattered rocks, with what success remains to be seen. Beneath these, but at a depth too great to be reached by a bore in the position of that at Rotokautuku, lies a great thickness of grey and green sandstones and green shales, which beds are full of comminuted plant-remains still retaining a great part of their carbon, and, should the gas- and oil-escapes have their source in these, borings will have to be made at points where the thickness of the superincumbent strata is less than at any place where boring for oil has hitherto been carried on. It is not, however, certain that these lower beds contain stores of mineral oil, and some stronger indications than the mere vicinity of gas-escapes will be required to justify such costly works as have already been proceeded with. Rocks may, in a sense, be saturated with inflammable gases and yet contain but small quantities of the oil supposed to be indicated by such gases. It is to be hoped that before long the question will be decided whether oil in payable quantities can be found in the East Cape district, in view of the large expenditure in connection with various prospecting-works which has already been incurred.

The various Tertiary formations on the coast-line between Waipiro (Open Bay) and Poverty Bay were examined and traced inland as far as the Upper Mata River, south of Hikurangi; this mountain and the main watershed as far as Arowhenua belonging to the Cretaceous system of rocks of which the oil-bearing series forms the base.

From Gisborne a line of section was examined along the Gisborne–Opotiki Road as far the Motu Bridge, where Old Secondary and Palæozoic rocks begin and continue to the shores of the Bay of Plenty. Here, as had already been ascertained both to the north-east and the south-west, the higher part of the main range is formed of much younger rocks than those appearing on the western slope, or which form the flanking ranges more to the northward. The higher part of the range in this line of section is formed of calcareous and greensand rocks corresponding to those which on the west coast of the South Island terminate the coal-bearing series of Greymouth and Westport.

Before leaving the work which has been performed by Mr. McKay during the period to which this report applies, it is

necessary to call attention to his highly-interesting critical paper regarding the position of the coal-bearing formations of South Canterbury, the geological position of which, as assigned by the department, had been questioned by Professor Hutton. The re-examination of the district by the Assistant Geologist appears conclusively to support the view maintained by the department, that there is no reason for assigning an exceptional position to the coal-seams, but that, on the contrary, although poorly developed, they are a horizontal extension of the same coal-bearing strata of Upper Cretaceous age which occur between Shag Point and the Waitaki, in the north-eastern district of Otago, and thence round the base of the Canterbury mountains north-west to the Waipara. The report in question (see page 79) deals so fully with the subject that further reference to it in this place is unnecessary.

During the last two summers Mr. Park has spent nine months in the examination of that portion of the North Island, between Marton and the source of the Waipa River, which is now being opened up by the survey in connection with the construction of the North Island Main Trunk Railway. The geological map, a reduction of which accompanies these reports, gives an outline of the geological structure of an area of nearly five thousand square miles, extending from the Manawatu River on the south to the Mokau River on the north, and from the sea-coast into the interior from the sources of the Rangitikei River to the sources of the Mokau, including the great central volcanic system of Ruapehu. In reporting, Mr. Park duly acknowledges that he had availed himself of the work of previous observers, and notably of a report by Mr. J. Coutts Crawford, F.G.S., who in 1864 made a preliminary survey of much of the same district on behalf of the Provincial Government of Wellington.

The first season's work was devoted by Mr. Park to the country between the Manawatu Gorge and the sources of the Wangaehu, on the south side of Ruapehu, and to the minute examination of, and collection of fossils from, the section exhibited on the coast-line between the Wanganui and Waingongoro Rivers on the south coast, and between Urenui and Mokau on the west coast. For the purpose of comparison, he also examined the sections of the Tertiary strata on the eastern side of the range between Masterton and Woodville. During the

succeeding season he examined the valley of the Wanganui River to its various sources, and followed the surveyed railway-line from the Murimotu country to the source of the Mokau, and thence followed down the valley of the Mokau, and examined the country from there to the source of the Waitotara River.

The general result of his work is, that the fossiliferous sands and gravels which are so largely developed in the country intersected by the lower part of the Wanganui River, and which are exposed along the coast-line as far west as the Kai-iwi, and underlie the high downs intersected by the Rangitikei River, and thence to the foot of the main range at the source of the Pohangina, are of Newer Pliocene age. These strata are of a somewhat estuarine character, or, at least, have been deposited within the immediate vicinity of the enclosing shore-line, and are characterized especially by the abundance of pumice and detritus from the volcanic ranges of the interior of the Island. On the other hand, the upper part of the Wanganui River, and, indeed, the greater part of the area examined, is composed of argillaceous strata capped by a formation of limestone representative of the Te Aute and Taueru series of the geological classification, and consisting largely of cemented fragments of shells. This limestone is the Waitotara limestone, which occurs at the sea-level at that place, but rises in a north-easterly direction, forming the capping stratum of a great plateau, intersected by deeply-cut river-valleys, until on the southern flanks of the Kaimanawa Range it reaches an altitude of 3,760ft., still maintaining the same mineral character of a thick band of coarse flaggy limestone, composed chiefly of oyster-shells and the valves of a large-sized sessile cirriped. Underneath the limestone the strata have an argillaceous character, and consist of the rock generally known by the Maori name of *papa*. But several other calcareous bands occur, and at points where the formation thins out against the older rocks plant-bearing beds are not uncommon. The total thickness of the formation is probably not less than 2,000ft., and the evidence seems to indicate that the limestone which forms the closing beds of the series was deposited at a tolerably uniform depth of sea, and that it has been subsequently tilted so as to acquire a general W.S.W. dip, from the locality marked Erewhon on the map to the sea-coast at Waitotara, of 1 in 90.

During the deposition of this limestone and the underlying beds there appears to have been no trace of the contemporaneous existence of any of the volcanic rocks that afterwards formed such an important feature in the geology of the interior district; so that the eruption of the trachyte lavas of Ruapehu must have commenced either during or subsequently to this local elevation of the Tertiary sea-bottom. From underneath this formation towards the source of the Wanganui, a still older Tertiary formation, representative probably of the Awatere series, appears at Paparoa, but has not been distinguished on the map, as it was apparently conformable to the overlying beds, the strike of which has a general north-westerly direction. Farther north and below these, with distinct unconformity, strata belonging to the upper part of the Cretaceo-tertiary occur, with a prevailing N.N.W. strike, consisting of marls, chalky limestones, and greensands, at the base of which workable coal-seams occur. The whole represent the development in the district of the Cretaceo-tertiary series. This formation presents several natural folds at moderate angles, which bring coal-seams within reach in successive lines parallel to the West Coast, the most westerly outcrop of coal being at a distance of ten miles inland from the mouth of the Mokau River, where it is already being mined to a very considerable extent. Towards the source of the Wanganui the greensands at the base of this formation are directly and unconformably overlain by the trachyte formation of the interior plateau, while the southern extension of the coal is completely cut off by the overlapping of the before-mentioned Tertiary strata. Nevertheless, in the broken country about the sources of the Patea and east of Mount Egmont the discovery of graphite, derived probably from the altered coal, would lead to the belief that the coal-bearing strata are no great depth beneath the surface in this district.

So far Mr. Park's examination of the coal-bearing rocks has shown that there exist in the Mokau district at least six distinct seams of coal, varying in thickness from 2ft. to 8ft., but dipping at moderate angles and rising into dry, sandy country intersected by valleys, and easily accessible not only from the tributaries of the Mokau River, but from the Tangarakau River, which is a very large branch of the Wanganui.

The recently-proved extension of the Mount Rochfort coal-

field north of the Mokihinui was also the subject of a special exploration and report by myself and also by Mr. McKay, with the result that a mine is now being opened, and railway access established, so as to render available enormously-thick seams of valuable bituminous coal, under circumstances which will admit of the coal being worked at much less expense than is involved in mining the higher parts of the field. The probable existence also of deep coals, which will only be available by shaft mining in an area to the north of the Mokihinui River, has been pretty well determined.

During the past season I have also re-examined the district of the Upper Buller Valley with especial reference to the manner in which the gold occurs at the Owen. This river rises from the south side of Mount Owen, and the geological structure of the country is almost identical with that of the Wangapeka district, which lies immediately on the north side of the same range, and which in 1869–70 excited so much interest, but, unfortunately, did not lead to any permanent result. The slates and sandstones belonging to the Te Anau formation (Upper Devonian) have been locally metamorphosed by extensive intrusion of granite on the eastward. Previously to the deposit of the Upper Cretaceous coal and limestone formations, which are extensively developed in a westerly and southerly direction, forming massive mountain-ranges, these Te Anau rocks appear to have undergone surface-decomposition to a very considerable extent, and in the decomposed rocks quartz-veins have been segregated which carry the gold. The soft and decomposed rock would have been unable to resist decomposition had it not been for the overlying limestones. The quartz-reefs have not yet been followed to any great extent, and are chiefly remarkable for the manner in which some of them expand into enormous blocks of quartz. The most promising mine is undoubtedly that known as the Enterprise, where the quartz is about 100ft. thick, and has been proved as a wedge-shaped mass to a depth of 90ft. below the outcrop. The mineral appearance of this quartz varies a good deal, some of it being highly ferruginous and vesicular, while other portions are either white, compact or vesicular quartz, or they contain a good deal of iron-pyrites. The analyses of several samples of ferruginous quartz, taken without special selection, however, return 5oz. of gold per ton; but all samples examined of the two other varieties did not

apparently contain more than traces of gold, and in some cases not even that could be found. In some samples of quartz from the field thin veins of a dark material were found, which proved, on chemical examination, to be due to the presence of a minute quantity of metallic bismuth, which is the first time the occurrence of this mineral has been detected in New Zealand.

Within a few miles of where the reefs are being worked a coal-seam occurs, the opening-up of which will be of considerable advantage to the district, as the quality of the coal is good and well adapted for smiths' work—a matter of great importance where mining operations are carried on. It is the same seam that I reported on in 1873, the following being the composition of the samples obtained on that and the present occasion :—

	1873.	1887.
Fixed carbon	52·85	57·76
Gas and oil	38·21	32·84
Water	4·82	7·01
Ash	4·12	2·39
	100·00	100·00

Evaporative power : Sample 1873, 6·87lb. ; 1887, 7·51lb.

During the early part of October Mr. Park was engaged in the Oamaru district with a view of determining the age and position of the coal at Ngapara, and the relation of the Waireka tufas to the Oamaru stone. A close examination of the heavy railway-cuttings on the Windsor–Livingstone line and the fine natural sections at Ngapara clearly showed that the coal occurs at the base of the Cretaceo-tertiary series, its very inferior quality being principally due to the loose porous nature of the strata in which it is enclosed.

At Teaneraki his view is that the Waireka tufas are distinctly conformable to the Ototara stone. They are apparently the horizontal equivalents of the sandstones underlying the Ototara stone at Ngapara, their tufaceous character being the results of volcanic activity, of which there is ample evidence in the neighbourhood.

Since Mr. Park's visit, Mr. Esdaile, who is evidently a close observer and careful collector, has kindly sent me his gatherings from the various strata referred to in this report. The fossils from the ferruginous greensands which are at the base exactly

agree with the fossils from the sandstone that immediately overlies the coal in the extreme north of New Zealand at Whangaparaoa, Whangarei, Kawakawa, Pahi, and Mokau, and, on the west coast of the South Island, the pitch-coal from West Wanganui to Greymouth, and which also occurs in the same relative superposition to the coal in the section at Waipara, Malvern Hills, Kakahu, in Canterbury. His fossils from the Waireka tufas agree with the Upper Greensand fossils of the Amuri section, and with those of the Onekakara beds farther south; and his fossils from the overlying calcareous and siliceous (flint-bearing and marly) beds are characteristic of the upper part of the Cretaceo-tertiary series. From the overlying calcareous sandstone, which Mr. Park considers to be the equivalent of the Ototara stone, Mr. Esdaile sent the tooth of a zeuglodont (probably genus Rhizoprion), which is, no doubt, the Kekenodon mentioned in the report. Regarding the portion of these upper calcareous rocks known locally as the Oamaru stone I am quite aware that there is still some confusion, as in that district any calcareous rock that can be profitably quarried is so designated without reference to its geological age.

Mr. Park next made a special examination of the recent coal-discovery on the banks of the Makarewa, near Forest Hill, Southland. The coal is of very fair quality, and, by a rough estimate, about a million tons are level-free and available for output on the lease of the Forest Hill Coal Company. The locality is easily accessible, being not more than a mile from the Government tramway from Winton.

He then examined the Middle Secondary rocks of Southland, commencing at the Otapiri Gorge, where a revision was made of former surveys. He traversed the most inaccessible part of the Hokonui Range, extending from the Otapiri River to West Peak, Dunsdale, and Hedgehope; and thence to the border of the Mataura Downs. The same rocks were also examined at the Mataura Falls, on the old road from Mataura to Clinton; and on the coast between Waipapa and Waikawa, where he connected with my former survey of 1864. During this survey a large amount of valuable information was collected, which is interesting as tending to prove that only two groups of strata of Middle Secondary age occur above the Bastion series, in the Hokonui Range.

From the 5th November to the end of the year an examina-

tion was made of the high mountainous country between Lake Wakatipu and Big Bay. This district attracted much attention about twenty years ago, but the interest of miners has been lately revived by the discovery of various minerals associated with gold, among which is the nickel alloy named awaruite.

With reference to the locality of Big Bay, I may state that it was discovered by myself in 1863, as previous to that time it was not delineated on any chart or map. It is situated immediately north of Martin's Bay, the headland between them (Cape Brown) being a sharp promontory terminating in a reef of rocks. Big Bay is four miles across from Cape Brown to Awarua Point, and has about the same depth. It is open to the west-north-west, but owing to its square shape it affords excellent shelter from all weathers south of west, the anchorage being within a rocky point close to the south-east corner of the bay in five fathoms of water and sandy bottom. There is, however, a fairly good boat-landing in southerly weather one mile within the headland.

In the north-east corner there is moderately good shelter from the north-west, with five-fathom soundings and a boat landing-place in fine weather. The beach at the head of the bay is coarse shingle, unlike that of Martin's Bay, which is a fine yellow sand. Black sand also occurs at Martin's Bay, but it is local and only in small quantities.

There is easy communication between the Kotuku River either round the coast or over a low saddle from the head of the Bay to the Okuri River, which enters the Kakapo Lake.

There is also a moderately easy saddle to the north-east, leading either to the Arawata River or to rivers entering the sea south of Cascade Point. A little gold has been got in some of the valleys, and gold obtained under large boulders on the beach in Big Bay is represented to be in very rough particles. The oldest rock in this district, with the exception of the crystalline rocks which form the back ranges, is a blue clay-schist much intersected by quartz-veins. This rock is broken by dykes of diorite, aphanite, hornblende, and other basic igneous rocks. With this association of rocks in the northern part of the Island there are generally found local patches of coarse alluvial gold, but in Otago the same formation, though extensively developed and well tested, has not yet proved to be auriferous, except to a slight extent in the Longwood Range, near Riverton.

Between the blue slates with quartz-veins and the schistose rocks of Cosmos Peak, and the main watershed towards the source of the Dart River, the igneous intrusive rocks above mentioned have been explored by Mr. Macfarlane (Geological Reports, 1876–77, p. 27) from abreast of Big Bay to the Jackson River, and to the south-west the continuation of this belt has been explored by Mr. McKay (Geological Reports, 1879–80, p. 118).

From this belt of country Mr. Macfarlane forwarded specimens of serpentine and dunite, describing the different rocks and their mode of occurrence at some length (see p. 28 of report above referred to). Mr. Macfarlane adds: "From where the formation shows in the Jackson the general course of the belt is S. 30° W., widening as it goes south, attaining its greatest width at the back of Big Bay—that is, presuming the red hill at this point is of the same character as the country I traversed. My farthest south was about twenty-three miles in a straight line from the Jackson to a point where the main branch of the Cascade falls about 200ft. in about 2 chains, and within about two miles of where the river comes in from the south-east. To the westward of the valley I find the slates and sandstones dipping to W. of an angle of 30°."

About a mile below the Cascade saddle the left-hand branch enters a gorge about two miles long. The river having cut clear through to a depth of 150ft. in places, a fine section of the formation is presented, which consists of a heavy conglomerate showing very complete stratification, and having a very slight dip to N.W. The river has cut clean through the conglomerates, exposing the older slates beneath (micaceous sandstone).

Mr. McKay describes the adjacent district as consisting of schistose rocks to the eastward of the intrusive or serpentine belt, and of Maitai and Te Anau rocks to the westward.

Of the serpentine belt he says: "The principal rock is a dark-green, almost black, serpentine; but not unfrequently light-grey talcose and asbestine rocks are present. Grey felsite rocks and fine-grained porphyritic and syenite rocks are abundant as massive developments, but seldom continue in dyke-like lines. Hypersthene and bronzite occur, although they are not plentiful in the southern end of the belt."

Chromic iron occurs on the north end of Lake Harris Range, but indications of copper were not detected, although ores of

this metal are found on the opposite side of the range in the serpentines of North Peak and the Lower Routeburn.

Generally along the western line sulphides are remarkably rare; and even in the schistose rocks, the iron, whether in lodes or disseminated through the mass of the rock, is usually present as an oxide.

The story relating to the occurrence of rich gold-deposits east of Red Mountain at the back of Big Bay appears to have no foundation in fact, and all accounts agree in placing the locality of a traditional and mythical find within the limit of the serpentine belt. If a gold-like metal was really found in the Upper Cascade, and in such quantity as has been reported, it is pretty evident that the finders mistook native copper for the more precious metal.

That gold exists in the district is not to be doubted, and there is some prospect that reefs may be found in the Maitai and Te Anau rocks to the westward of the belt of serpentine and intrusive rocks, and that they may also occur in the more schistose rocks to the eastward.

In 1862 I explored the country at the sources of the Arawata or Jackson River, having crossed the mountains from the Wanaka Lake by a *col* 7,000ft. in altitude on the west side of Mount Aspiring, and descended on the west slope till within about eight miles of the sea. Only schistose and slaty rocks were met with, similar to the formation which characterizes the Upper Shotover country lying north of the Wakatipu Lake, and of which it is no doubt a direct continuation.

The further exploration made during the past year was successfully carried out by Mr. Park under exceptional and trying circumstances. The rugged snow-covered ranges which had to be crossed, and the severity of the climate, rendered this an undertaking involving no small amount of personal danger: besides this, the scarcity of provisions and lack of shelter were at all times matters of great hardship and privation.

During this expedition the Red Mountain, situated at the sources of the Pyke and Cascade Rivers, received much attention, being closely examined on all sides, and traversed along its higher part from one end to the other. This region has always been looked upon with much favour by prospectors as a probable repository of valuable minerals; but the results of this survey, so far as can be determined by surface inspection, are not very

encouraging, no minerals having been found in commercial quantities. Of the metallic minerals chrome is the most abundant, but in this respect cannot compare with the chrome deposits of the Dun Mountain (Nelson). Copper, which is usually more or less common in olivine rocks, occurs only as minute traces; while the interesting nickel-iron alloy, *Awaruite*, first discovered by Mr. Skey in the auriferous sands from Barn Bay, and afterwards in the solid serpentine rock, has not yet been found in payable quantities.

From the Cascade Plateau to the Red Hill Range the olivine rocks have a much greater development than in any other part of New Zealand, forming lofty mountain-ranges rising to a height of 7,000ft. above the sea. North of the Red Mountain this mineral area has been little explored, thus still leaving open the possibility of deposits of economic value being found in this direction. During the past year or two a large amount of gold-prospecting has been done between Barn Bay and Martin's Bay, with, however, rather discouraging results. Traces of gold have been found at all parts of the coast; but up to the present time no attempt has been made to prospect the country inland from the sea, chiefly on account of the broken, bush-covered character of the ranges, and the difficulty of getting supplies.

As he returned Mr. Park made a special examination of Bob's Cove, Lake Wakatipu, with regard to the probable occurrence of coal there. The Cretaceo-tertiary rocks cover a very limited area on the margin of the lake, and, even if coal existed, of which there is no surface indication, the greater portion would be below water-level, the dip being to N.W.

Mr. Park's next work was to resume the examination of the interior of the North Island, and particularly of the district through which the North Island Trunk Railway is being constructed. He commenced by a special examination of a reported gold-discovery at Marton. The gold here is very fine, and too widely distributed to be payable. It is probably derived from the conglomerates associated with the calcareous members of the Wanganui series, which are composed of material originally obtained from the Kaimanawa and Ruahine Ranges.

A special report was also made on the gold-discovery at Waimarino. The gold occurs in the alluvial deposits of the rivers draining the west side of Ruapehu, but has not been found in payable quantities: indeed, the best prospects obtained were

only a few "colours" to the dish. The gold is probably of the same origin as that at Marton.

From the 26th to the end of March Mr. Park was engaged in the continuation of his work of last year in the King-country. He followed the survey-line of the Main Trunk Railway from Ohakune to Waimarino, and from Taumarunui to within a few miles of Te Kuiti; also the Wanganui River from Pipiriki to Taumarunui, and the valleys of the Mokau, Mokauiti, and Awakino, and the coast-line from the Mokau Heads to Tirua Point. The results of this work are very important, as showing a more extended development of the Cretaceo-tertiary rocks than was formerly supposed.

In order to connect the Taranaki coast with the Wanganui River excursions were made from Urenui to the head of the Patea, and from Stratford to the source of the Waitotara River, with satisfactory results.

Before returning to Wellington an examination was made of the bed of the Kapokonui Stream, near Manaia, where a boulder of graphite was picked up some years ago. With the exception of a few necks and dykes of volcanic rocks there are no outcrops of rocks *in sitû* in the neighbourhood, the whole of the Waimate Plains from the foot of Mount Egmont to the sea being covered to a great depth by volcanic drifts. The graphite, which was well waterworn, and no doubt derived from the drift, is probably a coal that has been altered by the volcanic heat of Mount Egmont during some early eruption.

Mr. Park proceeded to the Kaipara, Auckland, the object of his visit being to determine the probable existence of a coal-area at Paparoa. A number of sections bearing on this subject were examined at Batley; Komiti; on the west side of the Araparoa Arm; at Gibson's, on Te Ope Creek; at Paparoa; and between Pahi and the Gibraltar Rock, near Colbeck's Landing. A study of the latter was especially important, as showing the relation of the hydraulic limestone and greensands at Pahi to the hard limestone at the landing, which appears to be the horizontal equivalent of the Whangarei limestone. This limestone was traced to Paparoa, where it is underlain by greensands and fireclays which contain, near their base, a thick bed of carbonaceous shale which, on analysis by Mr. Skey in the Colonial Laboratory, was shown to be almost identical with the bituminous shales at Awanui, on the east coast of Auckland, referred to in Mr.

McKay's report, where extensive works have been undertaken to prove the extent of the petroleum deposits there.

It will be observed that one result of Mr. Park's survey on this occasion has been to lead him to discriminate between the Inoceramus beds and the hydraulic limestone, and thus to remove the discrepancy referred to in the last progress report regarding the Komiti section.

JAMES HECTOR.

Wellington, 30th September, 1887.

REFERENCE

1 Recent.
2 Lower Miocene & Upper Eocene.
3 Calcareous Sandstone = Ototara stone.
4 Marly Clays.
5 Waireka Tufas.
6 Onekakara Sands (greenish).
6a Moeraki boulder beds.
7 Greensands.
8 Kartigi Beach beds (Saurians).
9 Limonitic Sandstone.
10 Coal beds & Horse Range conglomerates.
11 Breccias, Sandstones & Blue Slates.
11a Blue Mountain Limestone. } MAITAI
12 Argillaceous beds, semi-metamorphic.
13 Schists.

VOLCANIC.

14 a. Miocene (Puke Tapu, Mt Royal &c) } Basalts
15 b. Cretaceo-Tertiary (Mount Charles) } Dolerites.
16 c. Felsite dykes.

Photolithographed at the General Survey Office, Wellington N.Z. October 1886.

ON THE YOUNG SECONDARY AND TERTIARY FORMATIONS OF EASTERN OTAGO—MOERAKI TO WAIKOUAITI.

REPORT BY ALEXANDER McKAY.

INSTRUCTIONS BY DR. HECTOR.

Wellington, 13th January, 1886.

BY direction of the Minister I have to request you to proceed to Palmerston, Otago, and continue the examination of the district, including Shag Valley, Horse Range, Shag Point, and Moeraki, with a view of ascertaining the relation of the coal formation, and especially the influence of the great fault discovered by the late Assistant Geologist, Mr. COX.

The chief object of your survey will be to ascertain if there is any reasonable hope of finding deep coal-seams that could be profitably worked for the supply of the district. . . . . .

JAMES HECTOR.

NARRATIVE.

I HAVE the honour to report that I left Wellington on the 14th of January, and, as instructed, was engaged in Marlborough and Canterbury Districts till the 25th, on which day I went from Christchurch to Palmerston, Otago, for the purpose of carrying out the above instructions. In the district around Palmerston, as far north as Moeraki, I was engaged till the 6th of March, when, in consequence of further instructions, work in this district was suspended till the 15th, on which date the further examinations necessary were commenced, and were finished on the 19th of March, on which date I went to Maheno and Kakanui.

REPORT.

My first examinations were made at Shag Point. During the winter of 1885 I accompanied the Director of the Geological Survey while examining the district adjoining Palmerston, and thus had some knowledge of the character and succession of the rocks in this part of the district. And, as it was of the highest importance to determine whether the rocks likely to contain coal-seams are of the same age at Shag Point and south of Shag Valley, apart from the stratigraphical evidence proving this, there were circumstances which rendered it highly desirable that the stratigraphical should be supplemented by palæontological proofs.

Accordingly, while other examinations were in progress, careful search was made for fossil remains, more especially in those beds that immediately overlie the coal-bearing lower portion of the Cretaceo-tertiary series.

Fossils had been found and collected from the beds overlying the coal at Shag Point prior to the first New Zealand Exhibition held in Dunedin during 1865 (Jurors' Reports, p. 263); and in the Catalogue of the Colonial Museum issued in 1870 three species of fossil shells are noted as coming from "ironstone concretions overlying the coal-seams." The genera mentioned are Cardium, Cyprina, and Inoceramus (Catalogue of Colonial Museum, 1870, p. 194). In after-years the precise locality whence these shells were obtained seems to have been lost sight of. At all events, when Dr. Haast examined Shag Point district in 1872 he failed to discover any fossil shells in the beds overlying the coal either at Shag Point or farther to the north (Geological Reports, 1873–74, pp. 24, 25). Professor Hutton seems to have been not more fortunate when he examined this part of the Otago District during 1874, for, though he mentions the finding of several casts of bivalve shells from the upper beds of Shag Point, and notes that the Otago Museum contains a fragment of an ammonite which is said to have come from this locality (Geology of Otago, p. 45), evidently the bivalves alluded to are those noted in the Colonial Museum Catalogue which would be brought under his notice while preparing the Catalogue of the Tertiary Mollusca of New Zealand issued in 1873. Of the ammonite Dr. Hector seems to have no knowledge; and, if from Shag Point, it must have been presented to the Otago Museum subsequent to 1866. Dr. Haast made special search for the reported fossiliferous beds along the southern base of Mount Vulcan, and among the boulders of Katiki Beach. I accompanied him during the trip, and, though we actually passed over beds which I have since found to be rich in fossil shells, we observed none; nor was a second attempt I made, in 1880, attended by better success, and, although almost my first work was to search the beach from Shag Point to the Railway Junction, I obtained but a few fragmentary shells that left me little hope of making important shell-collections valuable for the purpose I had in view.

In a former report (Geological Reports, 1883–84, pp. 60–62), I have pointed out the great importance of finding fossils in the beds immediately overlying the Shag Point coal, and what must be inferred from such collections if they at all agreed with the fossils elsewhere overlying the coal in South Canterbury and North-eastern Otago (Geological Reports, 1883–84, p. 60), and I was therefore much disappointed with the meagre results of my first essay on this occasion.

It seemed that the stratigraphy alone must be depended on, and to this I next addressed myself.

The great masses of conglomerate forming the Horse Range and Mount Vulcan, nearer the mouth of the Shag River, belong to the lower part of the coal-bearing beds, and from their character are evidently river-deposits analogous to those now forming the Canterbury Plains. Such coal-seams as are of any value are associated with the higher beds of this part of the Cretaceo-tertiary series. The upper seam is followed by a comparatively thin development of grits and conglomerates, and these are succeeded by estuarine beds of much finer grain. These latter, in turn, are followed by yet finer-grained beds passing upwards into intensely dark greensands, and there is nowhere to the north-east of the Horse Range a recurrence of beds at all resembling the coarse conglomerates at the base of the sequence. This makes comparatively easy the task of tracing and following the horizon of the principal coal-seams from Shag Point west and north-west wherever the disposition of the beds or the height and contour of the hills might favour their appearance.

In this way the outcrop usually of the limonitic sandstone and upper grits was followed from Shag Point Mine westward along the northern higher part of Mount Allan, and south-west along the western slopes of Mount Vulcan to the estuary of the Shag.

Thus terminated, the line of outcrop was again sought for in Puke Iwitai, and thence followed north and north-west along the south-east part of the Horse Range till descending its north-east slope the coal itself shows in the low grounds of Terapupu Valley.

On the north side of Terapupu Valley the coal outcrop trends north-west and crosses Trotter's Creek at the point where the road over the Horse Range leaves the creek-bed, the coal-seams from here striking more to the north in the direction of South Peak. The limonitic sandstone and upper grits run a long way up the south-east spur of South Peak, and, according to Dr. von Haast, reach the top of North Peak.

From North Peak the Palæozoic rocks descend its eastern slope to the southern branches of the Little Kuri, and where last seen it is the limonitic sandstone that is there in contact with the older rocks,—the upper grits, the coal, and the Horse Range conglomerates being absent, having thinned out farther to the south; but, as the limonitic sandstone can be followed foot by foot thus far, this gives the key to the reading of the section east to Hampden and Onekakara Beach. From Hampden the higher beds of the sequence may be traced south till the dark greensands are seen resting on the Katiki Beach beds in Trotter's Creek; and on the beach farther south the Moeraki boulder-beds and Onekakara beds, trending more to the south-east, pass out to sea between the lower part of Trotter's Creek and Moeraki Peninsula.

The Katiki Beach boulder-beds, next succeeding the limon-

itic sandstone, alone of the higher beds reach south of Terapupu Valley, and stretch through the depression between Puke Iwitai and Mount Vulcan to the Shag River.

The sequence forming the Cretaceo-tertiary series in this part of the district may be shortly described as—

1. *Breccias and Quartzose Conglomerates of the Horse Range, Trotter's Creek, and the South Part of Mount Vulcan:*

These beds are of very variable thickness, and, followed to the north, appear to thin out altogether abreast of North Peak. Their greatest development appears along Trotter's Creek and in Puke Iwitai, terminating the south-east part of the Horse Range. In the upper part of Trotter's Creek Gorge I estimate their thickness at 1,000ft., and their maximum thickness as seen in the south-east part of the Horse Range and in Puke Iwitai I should not place at more than from 1,200ft. to 1,500ft. With these as their upper part should be placed the finer grits, sandstones, and shales, carrying coal-seams of workable thickness.

Except at Shag Point there is usually but one coal-seam of any value, and, although there are two, perhaps three, seams on the western slope of Puke Iwitai, it is questionable if they are so situated or so thick that they can be worked with profit. In Terapupu Valley the seams are even yet less in thickness. A seam 4ft. thick, it was reported, occurred in Trotter's Creek, but, on visiting the locality, though the actual outcrop could not be examined, it was otherwise plain that only a thin seam could be present, or that it thinned so rapidly that no extent of workable coal could possibly occur in that vicinity. A 6in. seam is reported occurring on the eastern slope of South Peak, and, although prospecting has been carried on in some of the branches of the Little Kuri, no results have followed. It is therefore only in the vicinity of Shag Point that the coal appears to be of workable thickness.

2. *Upper Grits and Limonitic Sandstone:*

The shale band that, as a rule, overlies the upper coal-seam is sometimes not more than 2ft. thick, and at places may be said to be absent. As a general rule the coal is followed by moderately-coarse quartzose grit, alternating with bands of gritty sandstone. In Puke Iwitai the thickness of these beds may vary from 40ft. to 60ft. or more, and they are sometimes associated with beds of loose white quartz sands. Passing the last of the pebble-beds, the next rock consists of heavy-bedded sandstones that weather to a light-brown colour. This rock is characteristic at Shag Point, where it was first named limonitic sandstone by Dr. von Haast. In Woolshed Creek, not far from the Oamaru Road, over the Horse Range, pebble-beds are associated with these sandstones, and some bands are calcareous to a considerable extent, and some thin

bands of conglomerate are seen in Trotter's Creek, but the general character of the rock is not thereby affected. It preserves its dominant characters as far north as the Otepopo River, and, as the last of the more siliceous rocks, it is an excellent horizon from which to read the sequence upwards and downwards, or in either direction. It appears to have a greater development in the lower part of Trotter's Creek Gorge than elsewhere, and there it is not less than 100ft. thick. It is difficult to estimate its thickness between Shag Point and Rowley's Saddle, and north-west of Mount Vulcan, though it will not be greatly in error to put it at 100ft., which may roughly be said to be its average thickness. At several places these sandstones are fossiliferous, and near Shag Point Mine fossils occur in ferruginous calcareous nodules, which may thus be considered the locality whence the first collections were made (Catalogue of Colonial Museum, 1870, p. 194).

The uppermost beds of the limonitic sandstone approach in character the lowest of the next overlying; and where the junction takes place on the beach, north-west of Shag Point, the division may be taken at a peculiar fucoid band, above which the Katiki boulders begin; a similar fucoid band, more ferruginous than the ordinary rock on Puke Iwitai, seems also to be the boundary.

3. *Katiki Beach Beds:*

Above the fucoidal band the beds become more argillaceous and darker in colour, gradually becoming dark-grey or almost black as the higher beds are reached; but everywhere, when long exposed to the influence of the weather, the beds alter to a light-grey or pale yellowish-brown colour. They abound with irregular elliptic or spheroidal concretions of varying size and grain. Their thickness has been ascertained to be at least 300ft., and may be taken at 350ft., but this is nothing more than a rough estimate, since the strike and dip are scarcely ever observable, and the thickness may not be so great as it is here put.

Fossils are rare in these beds, and, except a few saurian remains found in the boulders of Katiki Beach, nothing else of any consequence has been collected from the beds.

4. *Lower Greensands:*

Intensely dark, almost black, greensands succeed the Katiki Beach beds, which, following the sequence north, first appear on the beach between Terapupu Creek and Trotter's Creek, about half a mile south of the railway-station. From the beach their strike carries them in a north-west direction till crossing Trotter's Creek, above and below the main road from Palmerston to Oamaru, where turning more to the north they are continued through Hampden, and, showing in the banks of the several small rivers falling into North Moeraki Bay, reach as far north as the Otepopo River

and the western slopes of Mount Charles. The beds dip at low angles, and their thickness is about 100ft.

5. *Moeraki Boulder-beds:*

Overlying the lower greensands are beds of grey sandstone and some beds of shaly clay, overlain by a considerable thickness of dark muds or carbonaceous clays, that are coal-black as seen in the first cutting (nearest the main line) of the Moeraki Branch Railway. These beds are more than 100ft. thick, and in their lower beds contain the celebrated Moeraki boulders, which, whether spherical or flattened, are usually enveloped in a coating of cone-in-cone limestone.

Flattened boulders covered with cone-in-cone are seen in the bed of the Little Kuri, opposite Hampden Railway-station, and on the hill opposite the black bituminous muds are seen to overlie the clays and sandstones, but apparently contain no boulders. The beds containing the boulders reach the beach at the mouth of the creek, but here also they are mostly flattened, and it is only where seen farther south, within tide-mark, that they take the perfectly spherical form. Farther south, in the cuttings of the Moeraki Railway, they seem represented by flaggy calcareous beds. The lower sandstones, as a light-brown or yellow flaggy sandstone, appear on the west slope of Mount Charles near Otepopo, and are there directly overlain by the volcanic rocks of that neighbourhood.

6. *Onekakara Beds:*

Beds of dark greensands, and greenish-grey more argillaceous beds, overlie the Moeraki boulder-beds. These may be 200ft. or more in thickness, but, as in the cliffs bounding the shore-line along Onekakara Beach the beds are repeated by a fault having its down-throw on the south side, there is, unless these facts are taken into consideration, a likelihood of the beds being assigned a greater thickness.

7. *Waireka Tufas, or Volcanic Breccias:*

These next succeed, and are well developed in White Bluff, at the north end of Onekakara Beach, but their greatest development lies farther to the north between Otepopo and the mouth of the Kakanui River. Dr. Haast mentions the occurrence of basaltic tufas in Moeraki Peninsula, associated with glauconitic deposits (Geological Reports, 1873–74, p. 26), and these may occupy the position of the Waireka tufas.

8. *Marly Clays of Moeraki Peninsula and White Bluff:*

These are the probable equivalents of the Maheno marls that on the left bank of the Kakanui are seen resting on the Waireka tufas, and at the same place replace or pass under the Ototara limestone. In White Bluff they are overlain by a volcanic breccia,

with nests of altered limestone, and in Moeraki Peninsula are also overlain by volcanic rocks.

This completes the sequence of the sedimentary beds, as seen in the Horse Range, south-east to Shag Point, and north to Onekakara Beach and White Bluff; and, after having examined the beds at various places, I was enabled to compare this with the sequence seen south of Shag Valley and in the neighbourhood of Palmerston.

The schistose rocks on which the Cretaceo-tertiary series south of the Shag River reposes, first appear at the western foot of Smyler's Peak, and there form the banks of Pleasant River. Following the river north-west, schists continue in the low ground of its narrow valley till reaching Taieri Peak, and are traceable a greater or lesser distance along the course of the small streams making junction from the south-west; but the slope towards Shag Valley and the flat-topped ridges to the south are formed of the quartzose grits that throughout the whole district constitute the basement beds of the Cretaceo-tertiary series. These are not nearly so thick as the beds they represent in the Horse Range and in Mount Vulcan. South of the Shag to beyond the Waikouaiti River they are scarcely at any place more than 200ft. in thickness. Sometimes the lowest beds are formed of material quite as coarse as any seen in Trotter's Creek, but, as a rule, this is less angular in character, and the larger quartz-boulders—8in. or 10in. in diameter—are all well rounded, even where the schistose material is angular.

The higher beds are finer in grain, and are associated with beds of dark micaceous shale, and with coal-seams at places. Where no coal-seam is present the limonitic sandstone overlying is full of impressions and cavities, due to the entombment of branches of trees in the original sands. The Katiki beach-beds follow, and, in the spurs running north from Smyler's Peak, contain the "ferruginous concretions" said to characterize the same beds on the north-east side of the Horse Range. These are mostly of elliptic form, and have not been traced south of Pleasant River. The higher part of these beds are grey sands, with abundance of green grains and some beds of greensand. They are of lighter colour than the higher part of their supposed equivalents exposed on the sea-coast; but I have pointed out that away from freshly-made exposures these beds become light-grey in colour, although very dark grey in the sea-face and freshly-made cuttings of any depth. They are overlain by intensely dark greensands, containing concretions and hard bands scarcely differing in appearance from the greensands, but in reality an iron ore of very fair quality.*

* Part of one of these concretions, analysed in the Colonial Laboratory, was found to contain 37 per cent. of iron. The rock scarcely differed in appearance from the greensands, only it was harder.

Within the Borough of Palmerston, and on the north side of Shag Valley, these greensands are overlain by more argillaceous beds, which weather white; but south of Palmerston by light-grey soft sandstone, with coarse impressions of plants. This is the horizon of the Moeraki boulder-beds; and on Mr. Muir's farm, near Harry's Peak, the beds much resemble those at Hampden.

At the western base of Puketapu, within the Borough of Palmerston, Dr. Hector estimates the thickness of the strata from the base of the last-mentioned beds to the schistose bed-rock at "nearly 1,000ft." (Geological Reports, 1884–85, p .184). The western slopes of Puketapu and Mount Royal are formed of the soft grey sandstones mentioned as overlying the dark greensands, and these are overlain by a considerable thickness of marly clays (with *Pecten zittelli* and several forms of Foraminifera), corresponding to the higher beds in Moeraki Peninsula. Together these beds are not less than 400ft. to 500ft. thick. They are followed by greensands immediately underlying the calcareous sandstones that represent the Ototara limestones. This latter has a considerable thickness, more than 200ft., and, dipping eastward at a low angle, occupies a considerable breadth of country to the seaward of Puketapu and Mount Royal. Within Bushy Park Estate, and along the coast-line to the south, Upper Eocene and Lower Miocene rocks cover these calcareous sandstones, and do so with some evidence of unconformity between them; but this unconformity is not so marked as it is generally supposed to be, and it is quite possible to maintain, with some show of reason, that the beds at least appear to be conformable.

Comparing the sequence here and the thickness of the different strata composing it with the rocks of the Horse Range, and those flanking it on the north-east to the sea, it will at once be evident that the basement of slaty breccias and quartzose grits has a far less thickness than in the Horse Range and along Trotter's Creek; but, excepting this fact, there is nothing in the character of the strata in either locality that is not strictly comparable, and, if the mere thickness of the beds be no argument against the identity of the strata as equivalent beds, the conclusion would be justified that they are of the same age and referable to the same formation. The greater thickness of the Horse Range conglomerates is a local feature even as regards this part of the district, and is mainly due to the rapid denudation of the older rocks in the vicinity, the proceeds of which were brought to rest within a comparatively small area: elsewhere a single bed of sandstone or a few feet of well-rolled quartz-grit might represent a greater lapse of time and amount of actual denudation than a hundred times their thickness in the Trotter's Creek breccias. The conglomerates of the Horse Range, followed to the north, lose in thickness as rapidly as they do when traced to the south-west. This is undoubted, and

it is less a marvel when it is borne in mind that in the Horse Range their thickness has been overrated. Local expansions of the same beds occur elsewhere, though in such localities they have been referred to the Tertiary period. An instance of this occurs farther to the south, where west of Silverstream, in the direction of the upper part of Mullocky Gully, the quartzose grits are, as regards thickness, quite comparable with those of the Horse Range; but this irregularity of the thickness of the beds underlying the coal-bearing horizon is a matter of small moment in determining the identity of the coal-beds themselves, or of what overlies them, and the depth at which coal may be looked for as indicated by the presence of the higher beds. From the coal to the marly clays of Moeraki Peninsula there is of limonitic sandstone 100ft., of Katiki Beach beds 350ft., lower greensands 100ft., Hampden and Onekakara beds 300ft., Moeraki clay 100ft.: or a total of 950ft. There is an equal thickness of each of these divisions in the section from the west side of Smyler's Peak through Palmerston to the Moeraki clays in Puketapu, and there is this even if it is admitted that the coal may be 200ft. from the base of the series.

So far, then, the evidence is that the coal of Shag Point and the north-east slope of the Horse Range occurs in the same formation as that extending south of the lower part of Shag Valley to the Waikouaiti River. The section from Mount Pleasant east across Mount Royal to the sea shows the coal in the position it should occupy; but generally the coal in this part of the district is in seams too small to be worked with profit. Unfortunately this is also the case over the greater part of the area covered by the coal-bearing rocks, and it is only in the neighbourhood of Shag Point that the seams are of workable thickness.

Near Palmerston, and over the entire watershed drained by Pleasant River west of the main road to Waikouaiti, there are so many natural exposures of the rocks of the coal-bearing series that if coal-seams really occur there ought to be no difficulty in making a discovery at one place or another. It is, however, thought that, though generally absent from the outcrop to the westward, seams may make and thicken as the beds are followed eastward into deeper ground. This may be, and there is some evidence at Shag Point that this does happen. Yet, south of Palmerston, search in the deep ground for that which does not show where the beds crop out must be regarded as a somewhat speculative undertaking, and, though there is no cause to discourage testing the field by boring, no site should be selected that lies to the east of the railway-line, and coming from the west the site should not lie far within the boundary of the greensands. Otherwise the works are apt to be abandoned, on account of the very considerable depth at which the coal is likely to be reached.

As regards the position of such trial bore along the north-and-

south line, that may be determined at any point, although it would appear that the prospects are better some distance to the south of Palmerston.

Whatever results may attend prospecting for coal in the lower part of Shag Valley, and the country to the south as far as the Waikouaiti River, it is of importance to prove that in this part of this district the rocks indicating the presence of coal are of the same age as the coal-bearing rocks of Shag Point.

This question may be dealt with in a manner by endeavouring to show what more than the mere presence of thick coal-seams distinguishes the beds at Shag Point from those to the south of Shag Valley, and what are the conditions that favour the occurrence of coal in any part of the district. There is also a broader method of dealing with this matter, itself no less practical than the more restricted and local aspect of the question. This would proceed to show whether the coalfields of South Canterbury and eastern Otago are of the same age among themselves, and at the same time not so greatly different in age from the main areas of coal all over New Zealand but that all may be included in the same series and fairly spoken of as the coal-formation of New Zealand; or whether our coalfields are of different ages, and the beds forming them were deposited under such different circumstances that in one the seams are regular and continuous, while in others the coal itself is of inferior quality, patchy, disconnected, and uncertain.

First, then, are there two coal-formations or only one present in the district? (The wider scope of the question cannot now be taken into consideration.) The answer, agreeably to what I shall show, is, There is but one; and I have already pointed out in part the grounds of my faith sufficient to have led us to a consideration of the remaining questions; but, as I hold in this a different view from those of other geologists who have examined the district, I am scarcely warranted to proceed without considering what has been advanced in favour of the opposite view, and giving some further proofs in support of my own.

When in 1871 Sir Julius von Haast examined Shag Point coalfield he considered the grits and limonitic sandstones overlying the uppermost of the Shag Point coal-seams as resting with unconformity on this and the lower grits of Mount Vulcan and the Horse Range, and at several places he noted that the upper grits were accompanied by coal-seams necessarily of younger age than that worked at Shag Point (Geological Reports, 1873–74, pp. 21–25). He did not visit the locality, but pronounced the coal outcrop on the east slope of Mount Pleasant, south of Palmerston, to belong to this younger formation.

During 1874–75 Professor Hutton examined Shag Point, Palmerston, and Moeraki districts, and also separated the Shag Point coal-bearing series from the rocks in Shag Valley and

farther south; but placed the unconformity higher in the sequence, as he included the limonitic sandstones and Katiki Beach beds with the Shag Point coal-bearing series and the conglomerates of the Horse Range. He further subdivided the rocks in and south of Shag Valley, referring the calcareous rocks of Mount Royal and Puketapu to the Eocene period, Oamaru formation, and the underlying greensands of Pleasant River, south of Palmerston, to the Miocene period, Pareora formation, and those along the south-west slopes of the Horse Range he endeavoured to show rest with a high degree of unconformity on the denuded lower part of the Shag Point series. He failed, however, to point out where it occurs, and what is the character of the unconformity that separates the Katiki Beach beds from the so-called Miocene beds of Hampden and Onekakara Beach, which it was necessary to do in order to prove the Miocene age of the beds south of Shag Valley and west of Puketapu and Mount Royal.

It is not difficult to show that Dr. Haast mistook the relation of the beds when he referred the upper grits and limonitic sandstones to a younger series than that to which the Shag Point coal belongs. The proofs to the contrary are that the limonitic sandstone yields an abundance of fossils, of which fully 40 per cent. are identical with those from the Black Oyster and Selwyn rapids beds in the Malvern Hills, several of which are also characteristic fossils of the Amuri series at Amuri Bluff. A cast of a brachiopod that agrees well with a dorsal valve of Spiriferina was found in thin beds at Little Puke Iwitai. From the Katiki Beach beds I collected saurian remains (of what species has yet to be determined), and, as these beds are followed by characteristic lower greensands as at the Waipara, it is not necessary to discuss this part of our inquiry any further.

It will thus be apparent that the beds south of Shag Valley, if of the age of the upper grit and limonitic sandstone, do not belong to a series younger than the Shag Point coal. On the other hand, supposing two formations present, if there is unconformity of the beds on the north-east side of the Horse Range, it should be between the Katiki Beach beds and the greensands that overlie, and, if not between these it must be placed between the greensands and the next overlying beds, as Professor Hutton refers the beds succeeding these, if not the greensands themselves, to the Miocene period (Geology of Otago, p. 57), and the underlying Shag Point series to the Upper Cretaceous period. He also supposes that the older series were greatly denuded or wholly removed from the area south of the Horse Range (now the lower part of Shag Valley and the country around Palmerston) prior to the deposit of any of the Tertiary rocks of that district (Geology of Otago, p. 50); and, if we accept the theory of the formation of Shag Valley in what may be called late Eocene times, or earlier, it seems that the Horse Range must then also have

assumed something like its present outlines. All this was necessary in order that the beds to the south might now be found resting on the tilted and denuded beds of the Horse Range itself.

According to Professor Hutton the geological structure of the district leaves no room to doubt this unconformable relation of the beds in the low grounds of Shag Valley to the Shag Point series in the Horse Range, and, as elsewhere in Otago the coal-beds are followed by marine strata, which, by their fossils, he refers to the Oamaru or to the Pareora formation, he is thus led to the conclusion that there is a younger coal-formation, to which must be referred the coals of Green Island, Tokomairiro, Kaitangata, Otepopo, Kakanui, and Big Hill; Shag Point and Mount Hamilton alone, of all the carbonaceous deposits of Otago, yielding coals of Cretaceous age. And, according to this showing, coals found in Shag Valley, or farther south in the same district, belong not to the Shag Point series.

For many years I have held the opposite view, and my work during the past year has confirmed me in the opinion that, leaving aside what may prove to be lignites of Miocene or older Pliocene date, all the coals of eastern Otago are of the same age.

Professor Hutton has never described in other than the most general terms the structure of the Horse Range, and has but asserted that younger beds rest against the rocks of its lower south-west slopes. I cannot therefore examine closely any opinions he may have formed respecting the character and precise age of the younger beds, or to what series, Oamaru or Pareora, they should be referred. But this is not necessary. What they are will be made apparent in what follows. I found the limonitic sandstone overlying the upper grit at Shag Point richly fossiliferous. I traced the fossiliferous band along the north and north-west slopes of Mount Allan, and thence west and south-west to the Shag River. The beds here dipping to W. are overlain in the low grounds between Mount Vulcan and Puke Iwitai by the Katiki Beach beds; but, the dip changing to E., the limonitic sandstone appears on the south spur of Puke Iwitai, and, striking N. along the higher part of the mountain at its northern end, is dislocated by a fault and set back some distance to the west. Along the whole eastern face of Puke Iwitai these beds are fossiliferous. Set to the west by the fault, they next appear on the very crest of the Horse Range, and are fossiliferous on the two first peaks following north-west. Farther north, their strike not altering to the north-west as much as the trend of the range, the beds do not longer reach to the higher part of the ridge, but follow the spurs leading to lower ground towards the north.

The upper grit and higher coal-seam do the same thing, and on the north-east slope of the range are exposed in the banks of Terapupu Creek as described by Dr. Von Haast; but, the dip of the

strata gradually becoming less as the beds are followed westward, and now not greater than the north-east slope of the range, if the coal-beds do not again reach the crest of the range, at least lower beds no longer cross the range and descend its lower slopes until the strike altering again to N., the dip being now E. and nearly the same as the slope of the range, causes the beds to reach the low grounds south-east of the gorge of Trotter's Creek. Dr. Von Haast ascertained this fact, and gives evidence of it in his mapping of the district.

I have already indicated what is the general structure of the district farther north, and may now proceed with a description of the south-west slope of the Horse Range, including the western face of Puke Iwitai.

Near the Oamaru Road crossing the range by way of Trotter's Creek gorge, the dip of the lowest beds is S.E., altering to E. as the beds are followed north, and in some measure conforming to the contour of the old surface upon which they rest. In this way from its higher part the same bed slopes down each side of the range, and in the mid-distance also dips to S.E.; but half a mile from the junction with the Palæozoic rocks a distinct anticline is formed, with very low dips to S.W. and N.E., and the thin coal-seams that appear near the top of the range again show in a small branch of Woolshed Creek, making junction with the main stream a little below Rich's old woolshed. The strike is now S.E. in the direction of Puke Iwitai, but as we follow onwards it alters more to S., and half a mile farther on the south-west side of the anticline is lost to observation. Farther to the south-east the beds that on the higher part of the range formed the north-east side of the low anticline descend the south-west side of the range, curving round to the south in their strike, and acquiring a higher dip, till in Puke Iwitai the strike is N.–S., and the dip E. at an angle of 60°.

Lying at the foot of the range, and forming the rolling downs and low hills between it and the alluvial flats of Shag Valley, are beds of calcareous sandstone (the same as in Puketapu and Mount Royal), blue or light-coloured clays (Moeraki Peninsula, White Bluff, &c.), Onekakara and Hampden beds, and the lower greensands of Hampden and Trotter's Creek. These are the beds which in Shag Valley and farther south constitute the Oamaru formation of Hutton, and what of the Pareora formation lies to the west of Puketapu and Mount Royal, and which are said to be here resting on the denuded Waipara beds of the Horse Range, the very apparent relation of which it is said enforces the conclusion that there is marked unconformity shown here, an unconformity which, though it be not observed, must be inferred from the general geological structure of the district. Nay, more, the assumption of an unconformity along the south-west base of the Horse Range rendered necessary the erosion of Shag Valley in

Eocene times, so as to admit deposits belonging to the Oamaru formation which have since filled it as far as Waihemo and Green Valley.

Were there no other than these beds present I should not prove conclusively the position I take up—at least not more conclusively than has already been done. I could but at most refer to the apparently conformable succession of the different members of the sequence on the north-east slopes of the Horse Range and farther north, and compare that with a like unbroken sequence south of Palmerston; but I should have also to explain the very apparent proofs of denudation with which the higher beds of the sequence rest or abut against the lower part, along the south-west base of the Horse Range. A fault alone could do this. Professor Hutton had no need to suppose such a fault present, as the unconformity was requisite to his theory; and a fault supposed is of no value whatever: it must be proved.

I accompanied Dr. Haast when in 1872 he examined the Shag Point district; and on the publication of Professor Hutton's Report on the Geology of Otago (having some knowledge of the country) I appreciated the force of his arguments in favour of unconformity, but, as there seemed to be here a contradiction of the evidence at every other point, I felt sure that eventually another explanation equally well founded and capable of being supported with proofs of a more direct kind would be found.

In 1880 I travelled the Palmerston–Oamaru main road as far as the foot of the Horse Range, and observed evidences of a fault at the junction of coal-measures with the higher beds of the Cretaceo-tertiary series; but, as the lower grits extend along the road towards Palmerston fully three-quarters of a mile from the foot of the range, this fault, however much prolonged and in whatever direction, could not wholly explain away the evidences in favour of unconformity which, it was said, are to be had along the range from Rich's woolshed to the southern shoulder of Puke Iwitai, as younger beds would still lie to the north-east of the fault-line, and a second fault would become necessary.

However, from the point of observation where it crossed the road-line the direction of the fault observed, if continued to the north-west, exactly limited the younger beds to the south-west, and the breccia conglomerates, the base of the Shag Point and Horse Range series, to the north-east. In this direction I followed the fault to Hutchison's lime-kiln three-quarters of a mile south-east of Harry's Peak.

The facts of this discovery were reported at the time; and the following year Mr. Cox was sent to examine the district (Geol. Reports, 1882, pp. xvi., 56). He seems never to have ascertained the precise position of this fault, and, in fact, makes no mention of it; but he describes another fault situate farther to the north-east, and nearly parallel thereto. This he

shows on the map accompanying his report. It exactly corcorresponds with the requirements of the theory of there being but one sequence of younger rocks from the calcareous sandstones of Puketapu and Mount Royal to the base of the Shag Point series. Nor does Mr. Cox hesitate in ascribing a Cretaceo-tertiary age to the beds lying to the south-west of the fault as far as Palmerston, or in referring to them as the equivalents of the Shag Point coal-beds. He goes further than this merely, for he points out the probable great extension of coal-measures in this direction; and, though coal has yet to be proven as actually occurring, this in no way lessens the value of the correlation he thus made. Unfortunately, Mr. Cox describes in nowise that part of the fault-line discovered by him which lies to the south-east of the main road from Palmerston to Oamaru; and this is the more to be regretted as this is that part of it that alone at the present time concerns us.

I commenced my examination of the beds in the low grounds along Woolshed Creek, not with the aim of proving this part of the fault indicated by Mr. Cox, but because I was attracted by the peculiar appearance and similarity to Puke Iwitai of a hill on the left bank of the creek, the south-east end of which lies abreast of Rich's woolshed. It is the upper grits alternating with sandstones and the lower beds of the limonitic sandstone that give to the higher part and south spur of Puke Iwitai the peculiar appearance it presents when viewed from the south.

The limonitic sandstone being fossiliferous in Puke Iwitai, I had already made the discovery, and collected largely from the beds, and, although, according to Professor Hutton's theory, it was most unlikely that the same beds should be present in the hill which I propose calling Little Puke Iwitai, I went thither to ascertain the reasons for the singular correspondence I had noticed. Finding the rocks corresponded exactly with those of Puke Iwitai just mentioned, a short search resulted in the discovery of fossils of the same species as those found in Puke Iwitai. The rocks of Little Puke Iwitai and part of the ridge to the north are indicated on Dr. Von Haast's map as belonging to the Older Tertiary period, "VI., *b*, clay-marl," and in the Section VI., *a*, Septaria beds; but the reference is singularly incomplete and inapplicable, as the rocks are conglomerates and ferruginous or calc-sandstones, and are spoken of in the body of the report as belonging to the newer conglomerates, &c. He also shows the beds in Section IV. of his report as highly (and in a singular manner) unconformable to the lower conglomerates. I traversed the line of section, and noticed that from the north-east as far as Woolshed Creek the section is much as represented in Dr. Haast's illustration; but there is not continuity between the high-dipping beds to the south-west and the nearly horizontal beds to the north-east, and, though there is some resemblance in the rocks, inasmuch as quartzose grits can

differ only in grain, colour, and induration, and other minor characters, still there is a distinct lack of proof that the beds pointed out are the same, and those to the north-east contain no fossils, and are not ferruginous or calcareous.

Supposing them to be what Dr. Von Haast thinks they are, stratigraphically these beds would be proof of the unconformity contended for by him, and, supposing them to have the relationship assigned them by Professor Hutton, they would prove that the Horse Range conglomerates and Shag Point series scarcely exceed 500ft. in thickness, and with the Katiki Beach beds added the total would be short of 1,000ft.

But, unless the Shag Point coals and the Horse Range conglomerates are of Lower Cretaceous date, Dr. Von Haast's assumption cannot be correct: and the evidence of the fossil flora is not in its favour. This is further proved by the fossil mollusca contained in the rocks of Little Puke Iwitai, and unless a fault be introduced to account for the presence of these beds in the position in which they occur it is hard to do so consistently with Professor Hutton's theory. And if a fault be admitted, then not only may the limonitic sandstone and Katiki Beach beds be present along the south-west slopes of the range, but the entire sequence might be accounted for in the same way should the higher beds prove to be present farther to the south-east; but in such a case unconformity would be no longer necessary, and there would be no proof of it as far as concerned the mere contact of younger beds with the lower beds of the sequence. The only evidence proving Professor Hutton's theory correct would then be unconformity between the Katiki Beach beds and the lower greensands; but none such has been shown, nor is such likely to be discovered.

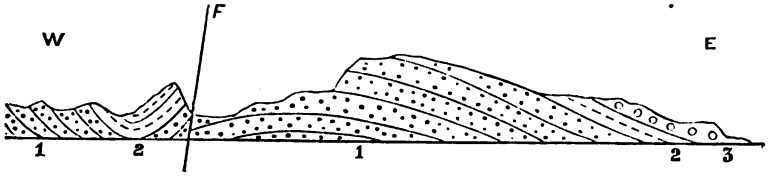
But, supposing unconformity present where indicated, if it were proved that the lower greensands, the Moeraki boulder-beds, and Onekakara beds were also thrown down by the fault, then Shag Valley could scarcely have been eroded until after the deposition of these supposed Miocene beds, and the calcareous sandstones of Puketapu and Mount Royal would not close the sequence along the south-west side of the fault, as they most certainly do.

But while palæontology contradicts Haast's unconformity, and the fault would disprove Hutton's theory, both are perfectly consistent with the views of the officers of the Geological Survey, when they assume that but one great sequence of beds are present, and that on the south-west side of the Horse Range the higher beds of this are brought into their present position by a fault running parallel with Woolshed Creek as far as the estuary of the Shag River, and, in all probability, out to sea.

The south-eastern part of the fault indicated by Mr. Cox would meet the requirements of the Geological Survey's contention; but, as he asserted rather than proved the existence of this fault, it becomes necessary to examine what evidence there is for

his assumption. He shows marls and concretionary sandstones the same as seen between Puke Iwitai and Mount Vulcan, and along the coast-line farther north, covering a considerable area south-west and west of the fault-line; but the presence of these alone, as Professor Hutton has shown, would not be conclusive evidence, since from the north they might be continuous through the depression between Puke Iwitai and Mount Vulcan, and prove nothing more than what Professor Hutton has always advanced—namely, the unconformity of these beds to the lower beds along the south-west slopes of the Horse Range farther to the north-west. Without further explanation than that given in his report, his mapping of this part of the district favours unconformity at the horizon where by Dr. Haast it is said to occur, and without proofs of the existence of the fault. Cox's mapping also favours unconformity where Professor Hutton places it, nothing but the straight black line on the map and the bare assertion being given in proof of its existence; and something more than this was requisite in proof of so important a discovery.

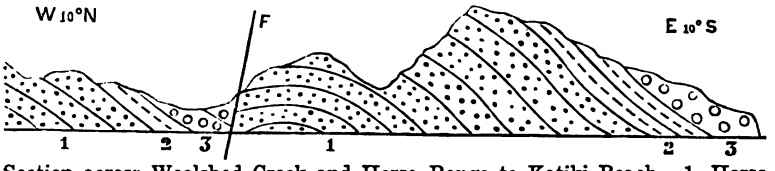
Little Puke Iwitai is not the only place within the watershed of Woolshed Creek where the fossils of the limonitic sandstones are found. At the north-west end of the hill the beds strike W. across the creek, and, resting on grits and shales with thin seams of coal, sweep round the north-west end of Churchstone Hill, and return with a S. strike along the opposite side of the syncline thus formed. Except where the beds cross the raised end of the syncline the dips on both sides are high. Before reaching abreast of the south-east end of Little Puke Iwitai the strike again alters, and the beds trend away to the westward, and are last seen in this direction some three-quarters of a mile distant.



Section from Oamaru Road east across Little Puke Iwitai to eastern slope of Horse Range. 1. Horse Range conglomerates. 2. Limonitic sandstone. 3. Katiki Beach beds. F. Fault.

Held at first within the narrow syncline, but on this opening to a greater width, following the limonitic sandstones, the next beds overlying are the Katiki Beach beds. These are characteristic as regards the non-concretionary material. The concretions are of all sizes, some of them immense: one built a church. Hence, the hill whence it was taken I have called "Churchstone Hill." The boulders are externally ferruginous in colour. I deem this important, because it has already been considered so, and because in this respect these contrast with the Septaria of the

Moeraki boulder-beds. Away from the narrow part of the syncline the dip of the beds is to E.

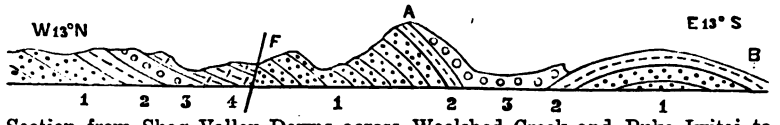


Section across Woolshed Creek and Horse Range to Katiki Beach. 1. Horse Range. 2. Limonitic sandstone. 3. Katiki Beach beds. F. Fault.

The limonitic sandstones in Little Puke Iwitai terminate suddenly at its south-east end. The beds probably extend farther, but the excavation of the valley of a small branch of Woolshed Creek has left no trace of them at the surface. Neither in the low flats of the main creek can the Katiki Beach beds be seen, and the fault-line, if its existence be admitted, is obscured by slope-deposits from the Horse Range; but, if the Katiki-Beach beds are not under the alluvium of the main valley, then what is? Certainly, lower beds belonging to the lower part of the Horse Range conglomerates; and to hold this is but to render the fault-line somewhat sinuous—a matter of little consequence; but we can have no radical unconformity between beds belonging to the same series showing at all other points complete conformity, with palæontological evidence confirmatory of the fact.

Hence strong suspicions of a fault. Down the valley there is no further evidence of a syncline, but the higher beds of the sequence that appear in this direction dip E. towards the Horse Range till interrupted and cut off by the fault. And the constant dip to E. gradually becoming S.E. is in favour of a fault rather than of uniformity.

The next beds are the lower greensands. They are seen in the hills bounding the narrow alluvial valley, and show in the middle of this where the road crosses the creek, and reach to the foot of the spurs formed of quartzose conglomerates, &c. They stretch down the south-west side of the valley to opposite Walsh's homestead, and, dipping E., admit of the appearance between them and the Horse Range of yet higher beds. Following their section west towards the north boundary of McGregor's farm, they are seen to rest with conformity on the Katiki Beach beds.



Section from Shag Valley Downs across Woolshed Creek and Puke Iwitai to Shag Point. 1. Horse Range conglomerates. 2. Limonitic sandstone. 3. Katiki Beach beds. 4. Lower greensands. F. Fault.

Here, then, without detecting evidences of it, we have passed Professor Hutton's unconformity; and this is but confirmatory of

what is seen in the Puketapu–Smyler's Peak section, and farther south in Mount Royal, and north-east of the Horse Range at all points. The next beds in the sequence are the Moeraki boulder-beds, and these are the next that, along the line of fault, follow the disappearance of the greensands. Freshly excavated these beds are dark sandy clays, and sometimes contain small quantities of carbonised vegetable matter, and other indications that have led to their being prospected for coal, but without any satisfactory result.

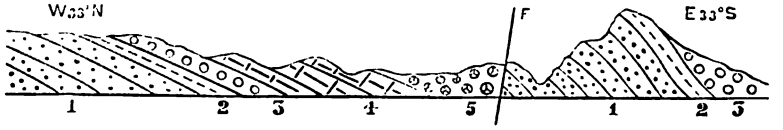
The down-throw and fault-line now become apparent at the surface, and the works undertaken in search for coal-seams show that the hade of the fault is at a very high angle, if not almost vertical.

Small seams of coal are found in the quartzose conglomerates on its north-east side close to the fault-line. These dip N. or N.N.E., the strata being here somewhat disturbed. The Moeraki boulder-beds can be seen to within 20ft. or 30ft. of where the grits show, and more to the north-west are traceable over a spur and down the slope to the next small creek. The direction of their boundary observed in connection with different elevations at which they are seen proves the high dip of the junction-line; and a shaft sunk in the gully to the south reached a depth of 80ft., and a bore-hole at the bottom of this some distance further, without passing through these beds. They are not, at this place, fossiliferous, but they contain septarian boulders, distinguished, as at Hampden, from the ferruginous boulders of Katiki Beach by their lighter colour and probably greater quantity of lime.

The map shows the extension of these beds to the south, but over a considerable part of their area in that direction they are obscured by younger deposits. With them are probably associated the Onekakara beds, but Post-tertiary surface-deposits prevent these being seen. And the only evidence of higher beds before reaching the calcareous sandstones of Puketapu is the material brought to the surface in digging a well on Mr. McLeod's farm opposite the south spur of Puke Iwitai. This shows the presence of the light-coloured marly clays of Moeraki Peninsula and Puketapu, but, as they are nowhere naturally exposed, I have mapped the Moeraki boulder-beds as occupying the obscure space between where last seen and the calcareous sandstones. In this I may have erred, but it is a matter of small importance, since it is undoubted that the sequence is closed by the calcareous sandstones, and elsewhere the character and succession of the beds downward to the lower greensand are made perfectly clear. The question that remains, and the more important, is, What is the nature of the contact? Of this there is no evidence at the surface, further than that the coal-measures, upper grits, and limonitic sandstone forming the southern spur and west face of Puke Iwitai terminate abruptly close to the line of fault prolonged yet farther to the south-east,

and the higher beds of 6*a* of the accompanying map closely adjoin these.

The limestones or calcareous sandstones of Puketapu are well exposed along the north bank of the Shag River, and form a flat table-land or terrace over the area indicated on the map. The beds lie nearly flat, but dip slightly to E. or N.E., which would bring them also to terminate abruptly at the fault-line, where they would be in contact with the Katiki Beach beds, east of Puke Iwitai; but there is no evidence here proving the presence of the fault, except the general structure of the district and the mode of contact inferred from and implied by what can be seen more to the north-west.



Section across Woolshed Creek and south end of Puke Iwitai to railway. 1. Horse Range conglomerates. 2. Limonitic sandstone. 3. Katiki Beach beds. 4. Lower greensands. 5. Moeraki boulder-beds. F. Fault.

That the general structural disposition of the beds south-west of the junction-line described bespeaks the presence of a fault may, apart from the more direct evidences of it, I think, be granted. There is visible evidence of unconformable relation at the northern end of Little Puke Iwitai as shown by Dr. Von Haast—Section IV. accompanying his report. This shows, I think, more probably displacement of the strata due to a fault; but the amount of vertical displacement is by no means as great here as farther down the valley of Woolshed Creek. Otherwise the lower beds to the west would first crop out farther to the north-west, or stand at higher angles than they do. Therefore towards the north-west the displacement becomes less, and is not observable where the fault crosses the lower grits, &c.; but towards the south-east it becomes more and more as we advance in that direction, and, while the same beds continue on the Horse Range side of the fault to the southern spur of Puke Iwitai from the opposite side, higher and yet higher beds of the same sequence are brought successively in contact with the lower beds of the sequence to which they themselves belong, and the contact made is abrupt, almost a vertical line.

This can be nothing else but a fault; but I will look at the evidence under the assumption that the junction-line is but the contact of unconformable strata deposited under ordinary conditions.

The facts favouring unconformity are stated thus: After the deposition of some 6,000ft. to 7,000ft. of Cretaceous strata, upheaval took place, and, although in eastern Otago the younger beds were not involved structurally among the older rocks form-

ing the Kakanui Mountains and the north-west part of the Horse Range, they were subject to flexure, and acquired dips to a degree not observed in the younger strata of the same district. Forming part of an elevated land during Eocene times, these Cretaceous rocks suffered denudation sufficient to effect their entire removal from some areas, and which in the Moeraki district was instrumental in the sculpturing of the Horse Range, producing the physical features that are dominant in the district at the present day. The beds to the south and west were wholly removed to below the level of the present coast-line, and Shag Valley was excavated, but by what agencies is not clearly stated, though it would appear this was a process of subaërial denudation. Depression of the land took place in Upper Eocene times, and the sea reached up Shag Valley to Waihemo and Pigroot. Again the land was raised, denudation followed, and the younger Eocene beds suffered severely; but it sank again, and young Miocene—Pareora beds—were deposited on the Eocene and Cretaceous beds indifferently. Elevated during older Pliocene times, oscillations of the land since then are not testified by the presence of marine deposits.

Between Trotter's Creek and Otepopo a curving beach and shelving shore formed the basement on which rested the Post-cretaceous deposits, lower greensands, Moeraki Septaria beds, and Onekakara beds. Between them and Shag Valley interposed the south-east part of the Horse Range, Rowley's Saddle, and Mount Vulcan to Shag Mouth, with gentle slopes to the north-east defying or spared the fury and effects of denudation. But south-west of the slopes of this range the younger beds were deposited under different conditions: the shore-line and the range behind is abrupt, and formed of material little able to resist denudation. The beds have suffered greatly, the structure of the range forbids the presence of the higher beds of the sequence, and the proceeds of continued denudation of the beds above water-line should have given character to the younger beds. These would then form beds of grit, sand, &c., resembling those in the Horse Range itself. At least, such material should largely mix with whatever beds were deposited, and under the least favourable conditions this to some extent must have been the case. Wherever the junction can be observed there is neither proof nor indication of this, and the higher beds have been deposited beyond the reach of gritty and pebbly material, and therefore beyond the reach of material from the beds with which they are now in contact.

Taken in connection with the evidence in favour of a fault, this absence of a rewash of the conglomerates and grits of the Horse Range makes it still less probable that the relation of the beds is such as admits of unconformity between them.

But uncommon or extraordinary conditions may be sufficient to explain the circumstances of the supposed unconformity between

these beds. Agreeably to what we actually know, I cannot conceive these to be other than an extremely bold coast-line springing from a comparatively deep sea that, shallowing to the south-west and west, admitted of the deposit of coarse material in that direction, while greensands, Septaria clays, marly clays, and limestones accumulated in deeper water and along the south-west base of the Horse Range; but this side of the Horse Range is not formed of granite cliffs, nor can we get rid of the objection that much material from it must have mingled with the younger beds, and have given them a character they have not. And it would be inconsistent with our supposition to find the greensands within a few miles overtopping the Horse Range, and here succeeded by other beds, reaching almost at sea-level.

Was, then, Mr. Cox right when he showed a fault beginning at Shag Mouth and extending along the south-west foot of the Horse Range to the Oamaru Road? Was he right when he referred the beds to the south-west to the Cretaceo-tertiary series, or in believing that the Shag Point coal-measures underlie the Palmerston flats; and was he justified in expressing his opinion to that effect, knowing that other geologists thought differently?

By evidence I have endeavoured to answer these queries in the affirmative, and by this consider he is justified.

Thus is disposed of one of the subjects under consideration. The other is contained in the two questions—(1) What more than the mere presence of thick coal-seams distinguishes the beds at Shag Point from those to the south? and (2) What are the conditions rendering probable the occurrence of coal in any part of the district? As answer to the first question it may be said that there is a less thickness of quartzose grits underlying the coal-beds, and that upwards the section is everywhere more complete if carried east to the sea. This last is not truly a distinction. Otherwise there is no distinction. The answer to the second question does not involve a statement of the necessary conditions, nor do I put the question as applying, however the answer may apply, to other parts or to the whole of New Zealand.

A study of the geology of the district makes it apparent that the Præ-cretaceous land-surface was irregular, probably hilly, if not mountainous. In the valleys between the hills and along the principal drainage-channels, the proceeds of denudation would lodge or be carried seawards, and according to the rate at which this went on the accumulation of vegetable matter would be favoured or retarded; but there could be no wide areas of coal-forming material until intervening ridges became obliterated, and comparatively flat low lands towards the sea had been formed.

Where, however, the deposits were purely terrestrial they would scarcely in any case ever top the dividing ridges of older rock, and it would only be more to the seaward and in lower grounds that these would wholly disappear prior to the advent of

marine conditions due to the gradual and continued sinking of the land. But before this took place there would probably exist a wide tract of fluvio-marine deposits, which purely fluviatile deposit might further raise, or a slight elevation of the land would render fit for the growth and accumulation of that which was afterwards to form a coal-seam, or under slightly different conditions a succession of coal-seams. But under sinking conditions of the land the event in almost all cases is that denudation becomes lessened, its proceeds less, and the sea encroaches, destroys, or effectively preserves the surface-beds over which it flows—sweeps up a valley, converting it into an estuary. The proceeds of denudation by the main channels are arrested farther inland, and, although not rendered insular nor devoid wholly of fluvio-marine deposits, the relatively higher grounds of the old land-surface fail to receive an equal share, and the reclamatory process, operating mainly farther inland, acts but feebly on such long spit-like projections, themselves not favourable to the encouragement of the vegetable growth required, and the consequence is an absence of coal-seams, conjointly with a lesser thickness of the first-formed fluvio-marine beds.

From the outcrop of the Palæozoic rocks in the Horse Range to Shag Mouth there is distinct evidence of a thickening of the strata under the coal, and the coal-seams themselves are thin to the landward, and gradually thicken in the direction of the sea, the thickest coal yet found being some distance eastward of the shore-line, showing that the reclamation I have spoken of was able to hold the sea in check for some considerable distance beyond the furthest point reached in the mine, and this probably despite the increased depth to be overcome the farther reclamation was pushed in that direction.

Coal-seams are of no more promising character near the so-called base of the series near the road-line across the Horse Range than they are within the valleys of the Shag and Pleasant Rivers, and but for the greater thickness of superincumbent strata rendering it difficult to reach the coal-seams it is quite possible there are coal-seams as thick as at Shag Point elsewhere along the coast to the south.

I have said that this explanation applies only to the district under consideration; and evidence drawn from outside it, showing that thick seams of coal have no great thickness of under-beds, compared with localities in the same field where coal is absent, is not a proof to the contrary.

ON THE GEOLOGY OF THE WESTERN PART OF WELLINGTON PROVINCIAL DISTRICT, AND PART OF TARANAKI.

REPORT BY JAMES PARK.

INSTRUCTIONS BY DR. HECTOR.

Wellington, 24th November, 1885.

DURING the ensuing season you will make a geological reconnaissance of the portion of line of country that is surveyed for the North Island Trunk Railway lying between Marton and the sources of the Waipa.

The chief practical objects to be kept in view are the relations and extent of the coal-bearing strata of the Upper Wanganui and Mokau, and the nature of the rocks occurring in the Tuhua country that are reported to be auriferous. Your examination will keep in view the following important points: (1) The relation which the Tertiary strata of the Lower Wanganui and Rangitikei districts bear to the strata of the Upper Wanganui which overlie the coal-formation; (2) the relation of the former beds to the older rocks of Ruahine and Kaimanawa Ranges; (3) the relation of the Tertiary strata to the great trachyte formations of the interior, of which Ruapehu is the earliest and greatest development.

This question has very great interest, as trachytic flocs occur on the coast north of the Mokau River that appear to be interbedded with or immediately to follow the grey marls with *Pecten zittelli* similar to those which you observed last year at Komiti Point. On the other hand, it has been generally held that the trachytic eruption of the central plateau took place subsequently to the deposition of all the Marine Tertiaries of the Wanganui River. The presence or absence of pumice-sands in the Marine Tertiary strata is thus a matter deserving of the closest observation.

In order to prepare yourself for comparing the strata, with which you will have to deal, with known horizons, you will first carefully examine the Manawatu Gorge, which will give you an opportunity of seeing a good section of the Rimutaka group of the Maitai system; also the calcareous and arenaceous strata of the Te Aute series (Miocene, III., *b*), and the relation to the pumice-sands (Pliocene, II., *c*).

The west slope of the Ruahine north of the Gorge should be examined, and the locality of the reported Pohangina reefs, on which you can make a special report; but you will particularly search for any evidence that indicates the outcrop of strata older than the Rangitikei Tertiary (papa) and younger than the Maitai

series of the Gorge. Keep in your mind the section entering the Wairoa Valley from the Waimea Plains of Nelson.

At Palmerston make your arrangements for the interior, engaging a field-hand and purchasing pack-horses. Then push on to the Moawhanga Falls, which are on the north or interior side of the forest-belt. Examine and collect from the splendid sections that are exhibited in this district by the valleys of the Rangitikei and its tributaries. Looking towards the base of the Ruahine Mountains from this point I observed isolated hills, which, I think, are limestone, standing up in the forest country. Cross the Rangitikei, and in the direction of these hills examine the section to the junction of the older rocks. Then make a rapid examination of the south flank of the Kaimanawas to the north limit of the Tertiary strata, which, as I observed in 1866, feather out on the old rocks at an altitude of 2,700ft. The beds at this point are littoral, and, being fossiliferous, must be carefully examined and fully collected from, so that a comparison may be instituted between the shallow- and deep-sea forms of life belonging to this period.

Next proceed to Murimotu, and then run a section from the Wanganui River to the west side of Ruapehu, which is entirely unknown country.

Your next centre of interest will be when the line reaches the Ongaruhe River, as there the coal crops out, and it may be necessary for you to cross to the Mokauiti and follow it down to the main valley, and, coming out at the Wairere Falls, where older rocks appear, run a careful section from this eastward to the trachytic plateau and across the older rocks of the Tuhua country.

Your work, after you leave Palmerston, will thus be a continuous section from south to north, and four sections transverse to your main line of route. You will take every opportunity that offers to communicate to me your working reports in accordance with the general instructions.

JAMES HECTOR.

NARRATIVE.

Wellington, 7th July, 1886.

I HAVE the honour to report that, in accordance with your instructions, I left Wellington on the 24th November and proceeded to Ashurst, situated at the lower end of the Manawatu Gorge, arriving there on the 27th. The next day I examined the section exposed in the Gorge, and on the 29th I visited the locality of the supposed reefs at Pohangina. On the 1st December I reached Palmerston, where I purchased pack-horses and made all the necessary arrangements for proceeding inland. On the 4th I passed through Hunterville, and proceeded along Murray's track to the open on the interior side of the forest-belt, reaching the Hautapu River on the 6th. From this date to the 23rd I was

engaged examining the country between the Hautapu and the Rangitikei, my work extending eastwards to the flanks of the Ruahine Range and northwards to the Kaimanawas.

On the 24th December I left Erehwon and proceeded in the direction of the Murimotu Plains, reaching Karioi on the 5th January, 1886, having examined the country near the sources of the Turakina on the way. On the 6th I proceeded through the bush to the Mangawhero, whence I ascended Raetihi, 3,400ft. high, situated between the Mangawhero and Manganui-a-te-ao rivers. On the 7th camp was shifted to the foot of Ruapehu, which was ascended the following day. The examination of the southern slopes of Ruapehu was continued to the 11th; and on the 12th camp was shifted to the foot of the Kaimanawas. From the 13th to the 17th I was engaged examining the country west of Ruapehu and Tongariro; and on the 18th Lake Roto-aira was reached, and on the following day Tokaanu. At the time of my visit to this district the Natives on the west side of Ruapehu, more especially those of Manganui-a-te-ao, strongly objected to the survey of their lands, and looked upon all survey parties with great suspicion and aversion On account of the obstruction of these Natives I was unable to proceed in the direction of Taumarunui, on the Upper Wanganui River. On the 23rd January the return journey was commenced, Marton being reached on the 2nd February, and Wellington on the 8th.

On the 12th February I again left Wellington and proceeded to Masterton, where I spent a few days examining the section from Rangitauma Hill to the Taueru. On the 17th I left for New Plymouth, reaching that place on the 20th. From the 22nd to the 27th I examined the coast-line from Waitara to the mouth of the Mokau. During the progress of this work fossils were collected at the Onaira and White Cliffs. From the 28th February to the 6th March I examined the Mokau River from its mouth to the Wairere Falls, a distance of about seventy miles. On the 8th I returned to New Plymouth, and on the 15th reached Wellington.

On the 12th April I left Wellington by the steamer "Stormbird," and arrived in Wanganui the following day. From the 14th to the 28th I was engaged examining the sections on the Wanganui River as far as the Kaiwaiki quarries, and along the coast to Kai-iwi. From the 29th April to the 10th May I examined the coast sections from Kai-iwi to Patea, at the same time making large collections of fossils at many places. On the 12th I returned to Wanganui, and the next day proceeded up the river in the steamer "Tuhua," reaching Pipiriki on the 15th. On the 17th I left Wanganui, and arrived in Wellington the following day.

POHANGINA REEFS.

The examination of these reefs was a preliminary work, and the following report was made on the 30th November:—

As instructed I visited the locality of reported auriferous quartz reefs at Pohangina on the 29th instant.

The precise locality is situated on a stream that rises on the western flanks of the Ruahine Range, and falls into the Pohangina about twenty-five miles above the junction of that river with the Manawatu at Ashurst. At the time of my visit the position at Pohangina was far from satisfactory. A great amount of prospecting had been done, but not a trace of gold could be found, and the men on the ground stated they were detained there not by the prospects, but by the perplexing results of assays of stone said to come from the Pohangina.

At present about ten gold-mining leases have been granted by the Waste Lands Board, and a surveyor is on the ground allocating the leases. So far, the prospecting has been conducted by two companies, the Palmerston Prospecting Company and the Wanganui Prospecting Company. The latter company keeps two men on the ground to watch its interests; while the former, since the first reports of gold here, has displayed great energy in its endeavours to prove the field, and has devoted a considerable portion of its funds to this purpose. Anderson, the original prospector, and an experienced miner named Rolf, were engaged to bare the reef, and this was effected on the 27th, two days before my visit. A brief examination showed that the supposed reef is not quartz, but a whitish-grey semi-crystalline limestone of good quality, which effervesces freely in weak acetic acid. It does not form a continuous bed, but is simply a lenticular mass interbedded with associated grey sandstones, jasperoid and black crumbling slaty shales.

With regard to the cherty quartz, specimens of which were forwarded to the Geological Department for analysis and yielded traces of gold, it may be as well to explain here that this stone was supplied from the bed of the stream, and not from the supposed reef, which some months ago was covered by a slip, and was only recovered, as already pointed out, two days before my visit. Thin streaks of cherty quartz occur plentifully in the jasperoid bands associated with the rock of the country; and a heavy band of this rock crosses the stream a short distance below the workings. This cherty quartz is found at many places in the Rimutaka series, from Wellington to the Manawatu Gorge, and in most instances has been shown to be auriferous, yielding however only traces of gold.

Before proceeding to the Pohangina I carefully examined the Gorge section. The rocks there are precisely the same as at the Pohangina, striking N.–S. generally at high angles. The whole series has been subjected to great lateral pressure, and most of the rocks are much shattered and broken, which has given rise to a great amount of slickenside among the black and red jasperoid slaty shales. The grey siliceous sandstones are often calcareous,

and in the Gorge alternate with black crumbling shales, forming thin-bedded strata. A similar section of the same rocks may be seen on the old coach-road across the Rimutaka Range.

Perhaps it may be as well to state that the workings at the reef consist of what is called a tunnel, about 30ft. long. This is merely a weak framework, constructed of posts or uprights, with cross-pieces, and three lengths of round saplings laid lengthwise, to protect the roof and sides. It stands at right angles to the slip which covered the reef, and extends about 5ft. into the solid, the remaining 25ft. being partly exposed and partly covered by loose material pulled down from the slip above.

Proceeding to the description of the general results of the season's work, I will in the first place describe the physical features of the country examined.

PHYSICAL FEATURES.

The area to be dealt with in this report embraces all that portion of the Province of Wellington west of the Ruahine Range and bounded on the north by the Kaimanawa Range and Ruapehu, and the greater part of Taranaki.

The principal mountains are the Ruahine and Kaimanawa Ranges, which maintain an average elevation of 4,000ft. or 5,000ft. above the sea. The former is the northern continuation of the Tararua Range, and is part of the main axis of the North Island. As a mountain-chain it is particularly well defined, more especially on its western side, which receives few outlying spurs or ranges of any importance. On the other hand, the Kaimanawas consist of a massive group of mountains rather than a continuous range, and from their central position form the watershed of many large rivers, all of which emerge from narrow gorges which extend back almost to their extreme sources. Among these rivers may be mentioned the Rangitikei, which drains its southern slopes; the Waikato, its western slopes; and the Mohaka and Ngaruroro Rivers, which drain its eastern and northern slopes.

Next in importance comes Ruapehu, which is situated at the extreme south limit of the great volcanic system which extends north to White Island. It is the highest peak in the North Island, and attains a height of almost 9,000ft. above the sea. It maintains large snow-fields throughout the year, this being mainly due to its massive character, which presents rather the appearance of a mountain-chain of stratified rocks than a mountain of volcanic origin. Immediately north of Ruapehu, and in the same line, is Tongariro, which culminates in Ngauruhoe, a fine volcanic cone 7,376ft. high. The only other mountain of importance in this area is Mount Egmont, a beautifully symmetrical volcanic cone, rising from the south-west coast of Taranaki to a height of 8,260ft. above the sea. It carries snow the greater part of the year, and

is the source of many important rivers which radiate in all directions from its summit.

The greater portion of this district west of the Ruahine Range and south of the Kaimanawas and Ruapehu is occupied by a great sloping plain, which gradually rises from sea-level, and attains a height of almost 4,000ft. on the southern slopes of the Kaimanawa Range, in a distance of about sixty miles. This plain is traversed by a number of large rivers which, with their tributaries, have a general course parallel to the fall of the country. The chief of these rivers are the Oroua, Rangitikei, Turakina, Wangaehu, Wanganui, Waitotara, Whenuakura, Patea, and Waitara.

The surface of this plain is very broken, consisting of steep ridges and deep gullies, and, with the exception of a narrow strip of clear country along the coast, is covered with a dense forest to its extreme north limit. A short distance inland the tops of the higher hills are occupied by limestones, which resist denudation better than the softer argillaceous and arenaceous rocks with which they are associated, and in consequence the hills and ridges are generally flat-topped, and very inaccessible on account of the calcareous strata presenting precipitous scarps on all sides. Being covered with a dense vegetation, these flat-topped hills do not afford good points of observation.

General Geological Structure.

The Ruahine and Kaimanawa Ranges, on the eastern and northern boundaries of this area, are composed of Palæozoic rocks that are chiefly grey siliceous sandstones, jaspcroid and black crumbling slaty shales. An isolated patch of somewhat similar rocks appears at the Wairere Falls, in the Upper Mokau.

The extinct volcanoes Ruapehu and Egmont are largely composed of trachytes; but rocks of a basic character appear to be among the earlier products of both.

Rocks of a Tertiary age occupy by far the greatest area in this district. That portion south of a line extended from Kai-iwi to the Ruahine Range passing south of the Huntervillo settlement is occupied by a great series of younger Tertiary rocks consisting of loose sandy shell-beds and blue clays. These appear to lie quite conformably on the loose shelly limestone which forms the crust of the sloping plain, but do not rise inland with this limestone, and seldom attain a height of more than 200ft. or 300ft. above the level of the sea.

In the Manawatu, Rangitikei, and Wanganui districts a large area is occupied by a great "drift" formation, which consists of coarse rusty gravels, silts, red and yellow sands, and clays. This formation is characterized by beds of lignite, which are found generally at its base. It extends from the Ruahine Range west to the foot of Mount Egmont, round which it sweeps to the Taranaki coast, whence it extends to the Mokau.

At its western boundary, near the Ruahine Range, the gravels, which are largely developed at its base, consist almost entirely of slate and sandstone pebbles, volcanic rocks being extremely rare; but, proceeding westward, the latter become more plentiful, and at Wanganui the drift-gravels consist mostly of volcanic material. In Taranaki, where this drift-formation is largely developed, the material is exclusively volcanic.

PREVIOUS GEOLOGICAL EXAMINATIONS.

In 1839 Dr. E. W. Dieffenbach, naturalist to the New Zealand Company, examined the coast between Taranaki and Mokau, and published the result of his observations in the first volume of his "New Zealand." He describes the volcanic rocks of Mount Egmont as trachytes, basalts, greenstones, and trachy-dolerites; and the Tertiary strata on the coast north of Waitara as stiff blue clays, which he says are overlain by a "great drift formation," consisting of yellow clays, sands, and conglomerates, with heavy deposits of lignite and drift timber near its base.

The coast between Wanganui and Patea was first described by the Hon. W. Mantell, in the Quarterly Journal of the Geological Society of London. Speaking of the blue clay at Wanganui, he says*: "The clay abounds in marine shells, all of existing species (?); the upper layers contain but few shells, but the lowermost abound in them, and they are in a perfect state—not drifted shells. In a stratum of sand at Wanganui the shells of a sandy-bottomed sea are found, with some fragments of large Nautili." On a subsequent occasion, under the heading "Blue Clay of Wanganui, North Island," Dr. Mantell says,† "A few specimens from this locality were sent in the present collection. . . . They are all of species existing in the South Pacific Ocean:" *Fusus nodosus*, Quoy; *Venericardia quoyii*, Lamarck; *Murex zealandicus*, Quoy; *Pecten asperrimus*, Lamarck; *Venus mesodesma*, Gray.

In 1860 Dr. Von Hochstetter passed through the Upper Mokau District on his way to Lake Taupo, and in his work on New Zealand, published in 1867, classifies the limestones and underlying clays seen at the Wairere Falls and Mokauiti, in his Lower Tertiary or brown-coal series.

Between 1861 and 1864 Mr. J. C. Crawford, F.G.S., late Provincial Geologist of Wellington, devoted some time to the geological exploration of the Rangitikei and Wanganui areas (Trans. N.Z. Inst., Vol. II., p. 353). He traversed the valleys of the Manawatu, Rangitikei, and Wanganui Rivers, and, having by this means acquired an intimate knowledge of their rock systems, divided the Tertiary strata, which occupy by far the largest area,

* Quarterly Journal of Geological Society, Vol. IV., p. 239.
† Quarterly Journal of Geological Society, Vol. VI., p. 332.

extending into Taranaki, as follows: (1) Upper sandstones; (2) blue clays; (3) coal shales.

It should be explained that this classification has reference only to the strata of the Rangitikei and Upper Wanganui, and does not deal with the sandy shell-beds and blue clays of the Lower Wanganui valley. At Parakino the shelly limestones which occur in the upper sandstones are characterized by the presence of *Ostrea ingens*, Zittel. At the "caves" below the junction of the Manganui-a-te-ao, at Puketapu and Paparoa, fossils were collected, most of which are still in the Colonial Museum.

Mr. Crawford found coal-outcrops at three places—viz., at the Tangarakau, at the Ohura junction, and above the junction of the Ongaruhe; and, in his remarks on the coal-measures of the Upper Wanganui, he says, "An inspection of the map will show that these three points lie in a straight line, on a strike of about N.N.E. The dip, where observed, appeared to be to S.W. I consider that there is little doubt that this formation extends throughout to the westward to the coal-seams of Mokau and the West Coast. It may be faulted and, in places, beyond reach; but the probabilities are of its extension throughout this district."

Mr. Crawford considered the rocks around Wanganui as Pleistocene, and gives the following tabular view of them in descending order (*Wellington Provincial Gazette*, 1862, p. 6):—

"*Tertiary.*

"(1.) Sand (siliceous and iron) in laminæ, sandhills at the top, exposing moa bones near the surface. I should suppose this stratum to be deposited by wind, could I thereby account for waterworn pebbles, mostly of igneous rock—lavas, tuffs, and traps—but also some of grauwacke and quartzite. Thickness, by estimation, 50ft. to 60ft. (2.) Ancient forest, with many stumps erect, but most of the trees lying prostrate, 5ft. (3.) A drift gravel of the same composition as No. 1, say, 20ft. thick, but irregular, and also containing fragments of Tertiaries. (4.) Soft yellow sandstone, say, 60ft. to 70ft. (5.) Blue clay, which appears to turn into a limestone near the sea-level, marine fossils, Ostrea, Pecten, Venus, Trochus, Terebratula.

"N.B.—There is much pumice in some of the upper strata.

"In ascending the river I was in hopes that we should find the strata tilted, and the lower beds cropping out, and that we should ascertain whether any Secondary or Palæozoic rocks lie beneath the Tertiaries, and also perhaps discover the altered or igneous rocks on which I suppose the Tertiaries, or other above-named stratified rocks, to rest; but as far as we ascended we found the same series of Tertiaries, with slight variations (as, for instance, I was unable to trace the ancient forest, No. 2, beyond a few miles from Wanganui), as at the settlement, preserving a remarkable horizontality, and consequently exposing nothing which lies beneath."

In 1866 Dr. Hector examined the coast section between New Plymouth and the White Cliffs, and describes newer Tertiary clays (Pliocene) lying highly unconformably on the blue clays of White Cliffs, to which he assigns a Miocene age (Geological Reports, 1866–67, p. 2).

Speculating as to the true origin of the petroleum at Taranaki, Dr. Hector says, "It is most probably to be looked for in the coal-seams that belong to the brown-coal formation that is believed to form the base of the series of Tertiary strata that extends under Mount Egmont and the valleys of the Wanganui and other rivers which enter the sea along the coast between Mokau and Otaki." —(Geological Reports, 1866–67, p. 9.)

In 1878 Dr. Hector made a further examination of the Waitara–White Cliffs section, and at the same time extended his survey to the Mokau basin (Geological Reports, 1878–79, p. 20). As the results of his observations at this time, he adopted the following classification of the rocks of this district:—

Lower Miocene—
Clay-marls of White Cliffs.

Middle Eocene—
Tufaceous greensands and breccias, with nummulitic limestone at base.

Cretaceo-tertiary—
Grey marls.
Chalk-marls.
Greensands.
Brown concretionary sandstone, with coal-seams.

Jurassic—
Marlstones.

Dr. Hector mentions the occurrence of several seams of coal at the Mokau, varying from 2ft. to 6ft. in thickness; and, in his remarks as to the extent of the coal formation, believes it strikes N.W.–S.E. from Kawhia Harbour till it meets the Wanganui River in the upper part of its course. As to the lateral extension of the coal-measures, he says: "A narrow belt of the Putataka (Jurassic) formation bounds the coal formation to the eastward, and forms the core of the anticline, as the country inland, where the valley expands into flat terrace-country, is again composed for some distance of the chalk-marls, which are again covered by the nummulitic limestone and the overlying tufaceous and trachyte series. Towards the source of the Mokau the country is open and moderately flat, and the limestones are frequently seen to rest on a floor of cherty slates (Palæozoic?), as at the Wairere Falls; the whole of the Cretaceo-tertiary formation, with its coal-seams, being absent."

In June, 1869, Mr. R. Pharazyn, F.G.S., in a paper on the geology of the coast between Kai-iwi and Waitotara, refers to the great Tertiary system of this district as equivalent to the Hawke's Bay system, "being apparently identical as to fossil contents" (Trans. N.Z. Inst., Vol. II., p. 159).

of New Zealand.

., F.R.S., DIRECTOR.

SKETCH MAP

THE

WELLINGTON PROVINCE

ND

TARANAKI.

86.

RT BY JAMES PARK

ALE.

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In September, 1869, Mr. John Buchanan, of the Geological Department, examined the coast between Patea and Wanganui, at the same time making large collections of fossils at many different points (Trans. N.Z. Inst., Vol. II., pp. 163–166). As the results of his survey, he divides the Wanganui beds into "an upper sandy and lower clay stratum, separated by a deposit of sand varying in thickness, being at least 12ft. in Shakespeare Cliff, at Wanganui; the whole being covered by a heavy deposit of sand and gravels containing a cemented gravel-bed, also of variable thickness."

Mr. Buchanan refers all the rocks between Wanganui and Patea to the sands and clays of Shakespeare Cliff, the loose sandy shell-beds, coarse shelly limestones, and calcareous sands between Kai-iwi and Waitotara being referred to his upper sandy stratum, and the blue clays between Whenuakura and Patea to his blue-clay stratum. He considers Shakespeare Cliff typical of the whole Tertiary system of the West Coast, and illustrates his paper with a fine sketch and section of this place.

The result of this classification is that the following fossils are cited, with others, as belonging to the upper sandy beds of Shakespeare Cliff: *Ostrea ingens*, Cardium No. 2 [*spatiosum*], Pecten No. 7 [*athlete*], and Pilæopsis,—all of which belong to an underlying and older formation.

In 1874 Mr. C. W. Purnell read a paper to the Wellington Philosophical Society "On the Wanganui Tertiaries" (Trans. N.Z. Inst., Vol. VII., p. 453); and in the following year Mr. T. W. Kirk made a collection of fossils from Wanganui for the Colonial Museum (Report of Geological Explorations, 1881, p. 123: Nos. 206–208).

In 1884 Captain Hutton made a rapid examination of Wanganui and Patea (Trans. N.Z. Inst., Vol. XVIII., p. 336). He takes Putiki Cliff, at Wanganui, as the type of the upper sandy shell-beds. These and the blue clays at the base of Shakespeare Cliff constitute his Putiki series, and, like Mr. Buchanan, he refers all the strata between Wanganui and Patea to this series. He attempts no further subdivisions of the above strata; and in the exhaustive list of fossils of his Wanganui system, which embraces the Putiki series, no specific localities are given; but he explains that, "of the localities attached to the names of the fossils, 'Putiki' means the upper sandy beds, and 'Shakespeare Cliff' the lower blue clays of Wanganui and Patea."

REPORT.

Before proceeding inland from Marton I made a careful examination of the Manawatu Gorge sections, in accordance with clause 3 of my instructions.

Upper End of Manawatu Gorge.—The rocks here consist of alternations of arenaceous and calcareous strata belonging to the Te Aute series (Upper Miocene), of the Geological Survey classification. Their relation to the older rocks of the Rimutaka group, and mode of occurrence, are illustrated by the following section :—

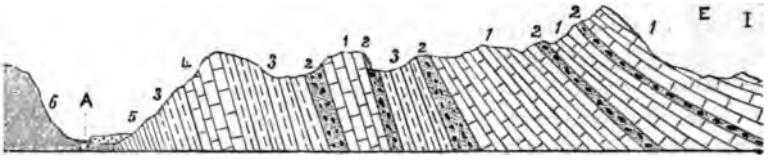


FIG. 1.

A. Manawatu Gorge Bridge. 1. Arenaceous shelly limestone; total thickness, 90ft. 2. Beds of sandstone and slate conglomerate, 31ft. 3. Pale marly greensands, 110ft. 4. Coarse gritty shelly limestone, 20ft. 5. Blue sandy clays, with *Ostrea ingens*, 50ft. (?) 6. Palæozoic sandstones and slaty shales.

The base of the Tertiary rocks cannot be seen at this place, being smothered by river gravels.

Manawatu Gorge Section.—At the upper end of the gorge, near the bridge, the rocks consist of compact grey siliceous sandstones and dark siliceous shales, alternating as thin beds, the harder sandstones forming narrow parallel ridges where the dip of the beds is high. Their general strike is N.–S., and, although standing at high angles and much shattered and broken, they appear to have a westerly dip.

About a mile further down the gorge these thin-bedded rocks are seen to overlie red siliceous slaty shales, which are even more shattered than the overlying beds. Bands of red cherty jasper with thin streaks of quartz are of frequent occurrence in these red crumbling shales, and are found—although less frequently—throughout the whole series. These jasperoid rocks do not always occur in bands, but often in large irregular masses.

The whole of this series of old rocks have been subjected to great lateral pressure, and are intersected by faults and fissures in every direction. Where sliding has taken place the fissures are lined with slickensides, more especially in the vicinity of the hard jasperoid rocks.

The general trend of the gorge is between west and north, and, as this is pretty well the strike of the rocks, they are repeatedly crossed by the river in its course of four miles through the gorge, thereby giving an impression of faulting that does not exist.

Pohangina Section.—A remarkably clear section, showing a great thickness of the pumice-sand series, is exposed in the high banks of the Pohangina, near Ashurst.

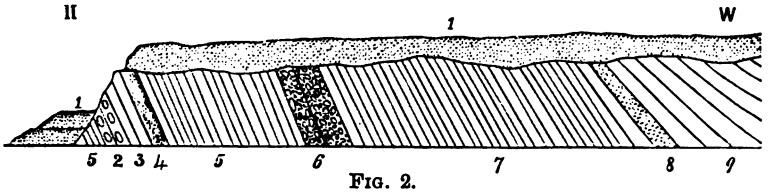


FIG. 2.

1. Terrace-gravels. 2. Quartz-sands with pieces of water-worn pumice, 15ft. 3. Fine silts and clays, 15ft. 4. Fine gravels, 7ft. 5. Fine silts and clays, 48ft. 6. Heavy bed of loose shingle, 15ft. 7. Micaceous silts and clays, 200ft. 8. Red rusty gravels, 12ft. 9. Sands and clays, 25ft.

At the foot of the cliffs near Bed No. 7 I picked up several fragments of sandy clay containing casts of *Venus stuchburyi*, Gray, and a few indistinct gasteropods. I could not see the fossils *in situ*, but they did not appear to have travelled far.

The pumice-sands and gravels extend up the Pohangina a great distance, but how far beyond the reefs I could not ascertain. They form high cliffs on both banks, and are generally lying flat or at low angles; they have, however, been subjected to great local disturbances, and a short distance above the junction of Coal Creek are standing on end. Several seams of lignite occur in these beds, and one 6ft. thick may be seen in the banks of Coal Creek, about a mile above the junction.

Passing up the stream where prospecting for gold has been carried on, these beds assume a dip to the west, and the following section is seen between the Pohangina and the reefs:—

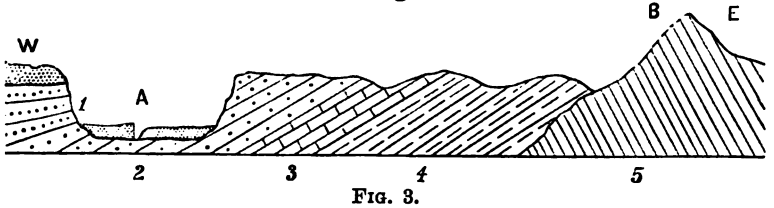


FIG. 3.

1. Sands and clays with beds of rusty gravels. 2. Pale-blue sandy clays. 3. Sandy shell-bed (limestone). 4. Pale-blue sandy clays. 5. Palæozoic rocks. A. Pohangina River. B. Ruahine Range.

Bed No. 2 is composed largely of broken shells, the best preserved and most common of which are,—

Waldheimia lenticularis, *Deshayes.*	Mytilus edulis, *Reeve.*
Terebratella cruenta, *Dillwyn.*	Ostrea edulis, *Linnæus.*
Cardita australis, *Lamarck.*	Pecten radiatus, *Hutton.*
Venus mesodesma, *Quoy.*	

Marton to Hautapu.—Around Marton the country is obscured by recent gravels and clays; but well-borings show that below these occurs a great thickness of sandy clays with recent shells. These beds continue inland to Hunterville, and at the entrance to the bush are underlain by blue clays which form high cliffs on the banks of the Rangitikei. About two miles beyond Hunterville, on the road to Pukiori clearing, occurs a cement sandy shell-

bed or limestone, containing a Balanus and Chione in great abundance, also *Rotella zealandica*, Hombron, and *Balanus decorus*. Beyond this, blue clays continue the whole way through the bush, but on account of the dense vegetation little can be seen of their exact nature and disposition. In many places they contain fossils, the most common form being *Turritella tricincta*, Hutton.

Just before the large clearing (about thirty miles from Hunterville) is reached, yellowish-blue sandy clays make their appearance, and continue to the Hautapu River. Interbedded with these occur numerous bands or layers of hard argillaceous concretionary masses, in which fossils are plentiful, the most characteristic form being *Pecten radiatus*.

At the Hautapu River these beds are underlain, conformably, by blue clays, in which I could find no fossils. At the Native cultivations on the banks of the river, about a mile below where Murray's track emerges from the bush, the blue clays and overlying sandy clays are overlain, unconformably, by a great thickness of volcanic agglomerate that extends down the right bank of the Hautapu in the direction of the Rangitikei junction. It appears to have covered a very large area, forming a high plateau, the remains of which may still be traced in the flat-topped hills or ranges along the course of the river. The general elevation of these hills is about 2,000ft. above the sea, or from 400ft. to 600ft. above the level of the surrounding valleys, to which they generally present steep scarps. In many instances the volcanic agglomerate has been entirely denuded from the higher levels, a few loose boulders being all that now marks its former existence in these places.

The rocks composing this agglomerate are compact and vesicular trachytes, trachyte-porphyries, and dolerites. These occur as rounded boulders, often of immense size, set in a soft decomposing tufaceous matrix of many variegated colours. In this and many other respects these rocks closely resemble the trachydolerite agglomerates and tufas of the Upper Waipa and Pirongia The bed of the Hautapu, as far down as I followed it, is thickly strewn with these boulders, and this is no doubt the source of the volcanic boulders noted by Mr. Crawford in the Rangitikei River, below the junction of the Hautapu (Trans. N.Z. Institute, Vol. II., p. 353).

Near the top of one of the hills, on the right bank of the Hautapu, there is a small outcrop of a coarse shelly limestone containing—

Venus mesodesma, *Quoy*.	Pecten triphooki, *Zittel*.
Lima bullata, *Born*.	Anomia undata, *Hutton*.
Ostrea edulis (?), *Linnæus*.	Ancillaria australis, *Sowb*.

This limestone lies quite conformably on the yellowish-blue sandy clays, and its relation to the underlying beds and overlying volcanic agglomerate is illustrated by the following section :—

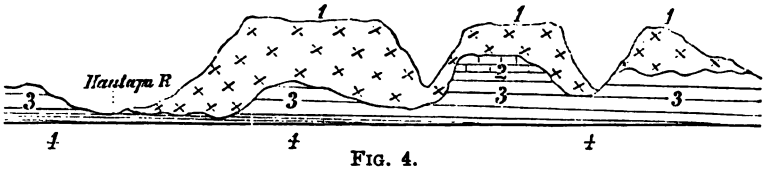


FIG. 4.

1. Volcanic agglomerate. 2. Shelly limestone. 3. Yellowish-blue sandy clays. 4. Blue clays.

Continuing the above section farther north, blue clays with calcareous shell-beds are seen at the Hautapu Falls, from which the following fossils were obtained: *Cyclina dispar*, Hutton; *Ostrea edulis* (?), Linnæus; *Dosinia grayi*, Zittel; and a Placunanomia.

Erehwon.—At the foot of the south flanks of the Kaimanawa Range, the Moawhango River has cut its course between the Palæozoic rocks and the Tertiaries, which thus form a long east-and-west line of high scarp, from 500ft. to 600ft. above the river. About four miles from Erehwon the Moawhango breaks through this scarp-line and flows south for some miles, in a narrow precipitous gorge. On the saddle, between the east branch of the Moawhango and a large stream flowing into the Rangitikei, the young rocks flank on to the Kaimanawas, and run out at an attitude of 3,200ft.

The Tertiary rocks exposed at this place are, in descending order,—

1. Bed of red loamy earth, with pumice-sand throughout, 3ft.
2. Coarse flaggy shell-limestone, 50ft.
3. Blue sandy clays, with argillaceous calcareous bands, 200ft.
4. Coarse shelly limestone, 10ft.
5. Blue sandy clays, sometimes micaceous, with argillaceous calcareous bands, 300ft.

Bed No. 1 is a superficial deposit, and unconformable to the underlying limestone. On account of the large percentage of pumice which it contains, it forms a light soil of poor quality. It appears to be wide-spread in its distribution, and in the direction of Tongariro it contains a larger amount of pumice-sand, and consequently gets too poor to sustain anything but a stunted vegetation.

Bed No. 2 is composed entirely of broken shells and sandstone pebbles. It has a flaggy or tabular character, and, where it comes in contact with the Palæozoic rocks, passes into a pebbly conglomerate. Its shells are generally too broken to be of much value, but the following forms were collected:—

Crypta profunda, *Hutton*.
Turbo granosus, *Lamarck*.
Pleurotoma sulcata (?), *Hutton*.
Struthiolaria papulosa, *Martyn*.
Anomia alectus, *Gray*.
Pecten triphooki, *Zittel*.
Pecten convexus, *Quoy*.
Pectunculus laticostatus, *Zittel*.
Ostrea edulis (?), *Linnæus*.

Bed No. 3 consists of blue sandy clays with bands of limestone containing *Cyclina dispar* in great abundance.

Bed No. 5 contains a large number of finely-preserved fossils, a collection of which includes the following forms :—

Lutraria solida, *Hutton.*
Zenatia acinaces, *Quoy.*
Mactra æquilatera, *Deshayes.*
Dosinia subrosea (?), *Gray.*
Ostrea, sp. ind.
Ostrea edulis (?), *Linnæus.*
Mytilus edulis, *Reeve.*
Hemimactra notata, *Hutton.*
Callista elegans, *Hutton.*
Pectunculus globosus, *Hutton.*
Pecten radiatus, *Hutton.*
Pecten triphooki, *Zittel.*
Tellina deltoidalis, *Lamarck.*
Lima bullata, *Born.*
Anomia undata, *Hutton.*
Barnea similis, *Gray.*
Cyclina dispar, *Hutton.*
Ancillaria australis, *Sowb.*
Struthiolaria tuberculata, *Hutton.*
Crepidula incurva, *Zittel.*
Trochita novæ-zealandiæ, *Lesson.*
Trochita dilatata, *Zittel.*
Cominella maculata, var. B, *Mar.*
Oliva neo-zealanica (?), *Hutton.*

The whole of these beds dip S. at an angle of about 5°.

Between Erehwon station and the Rangitikei River there is an isolated hill of Palæozoic rock, which rises to a height of 2,900ft. above the sea. It is surrounded on all sides by Tertiary strata, which are well exposed in the gorge of a small stream on its eastern side, where the following sequence is seen :—

1. Coarse pebbly limestone and conglomerate.
2. Sandy clays.
3. Hard shelly limestone band.
4. Blue clays and yellow micaceous sandstone, resting on Palæozoic rocks.

The yellow micaceous sandstone of Bed No. 4 contains thin layers of yellow clays with well-preserved fossil plants, of which a Fagus and a Panax are the most characteristic. A collection of these plants was made within a few feet of the point of contact between the Palæozoic rocks and the micaceous sandstone, which however is of marine origin, containing an abundance of fossils, which are chiefly *Crypta profunda* and *Trochita dilatata.*

Upper Rangitikei.—On the right bank of the Rangitikei, near the Erehwon wool-scouring sheds, occurs an outcrop of Palæozoic rocks, and in following down the valley several other isolated patches of the same rocks may be seen. They consist of grey siliceous sandstones and dark argillaceous slaty shales; and in the river-bed boulders of red and purple jasperoid rocks and slate-breccias are quite common.

From the river-crossing the river flows between high precipitous walls of Tertiary strata, and in places these approach so close as to confine it in narrow gorges that are impassable for miles. The Rangitikei has cut its channel through several bands of hard shell-limestone, and yellow and blue sandy clays, down to the blue clay which is the lowest rock exposed in the sections in this locality. The whole of the Tertiary sequence in this part of the district is lying at very flat angles with a general southerly dip, and on both sides of the Rangitikei Valley the country rises by a succession of wide terraces or flat-topped hills, which increase in height as they recede from the river. The top of each terrace is occupied by a bed of limestone or other calcareous strata, which

generally presents steep scarps and protects the underlying softer strata from rapid denudation.

The disposition of the rocks from Erehwon to the flanks of the Ruahine Range is illustrated by the following section:—

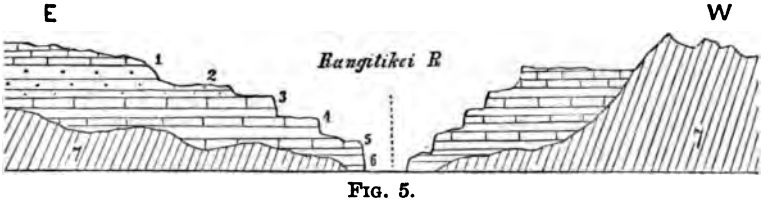


FIG. 5.

1. Coarse flaggy limestone, 60ft. 2. Blue sandy clays, with concretions, 550ft. 3. Thin-bedded yellow sands and clays, 200ft. 4. Blue argillaceous sandy beds, 200ft. 5. Soft yellow micaceous sandstone, 250ft. 6. Blue sandy clays, 450ft. 7. Palæozoic rocks.

Bed No. 1 runs out on the old rocks of the Ruahine Range at an altitude of 3,450ft. above the sea, and on both sides of the Rangitikei occupies the tops of a number of flat-topped hills, covered with forest.

In the upper part of Bed No. 3 there occurs a thick band of coarse flaggy limestone, chiefly composed of broken Balanus and oysters.

In the valley of the Rangitikei large blocks of pumice are plentiful, and in many cases terraces of pumice-sand have been formed by the river. On the banks of the Oarangi, a branch of the Moawhango, may be seen terraces of white and pink pumice, similar to those mentioned above; and on the highest parts of the Kaimanawa Range pumice occurs to a depth of several feet, in sheltered places.

South Slopes of Kaimanawas.—It has been already pointed out that the Tertiary rocks form a great scarp-line on the south slopes of this range, extending from the Rangitikei to the Murimotu Plain; but a few isolated patches of these still exist on the higher parts of the range, and in one place they attain a height of 3,725ft. above the sea. The position of the Tertiary strata will be best understood by reference to the accompanying diagram:—

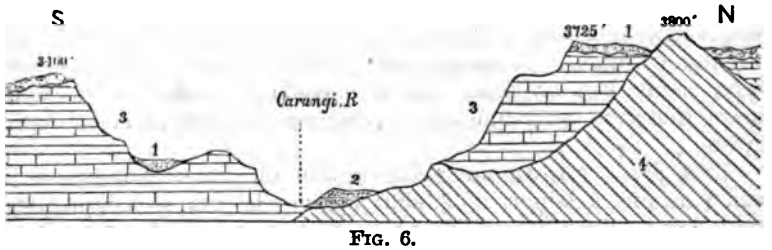


FIG. 6.

1. Superficial loamy clay, with pumice. 2. Pumice terraces. 3. Tertiary strata. 4. Palæozoic rocks.

The Palæozoic rocks of the Kaimanawa Range consist of grey

and green sandstones, and dark argillaceous slaty shales. On the west side of the range, facing Ruapehu and Tongariro, they are much contorted and broken, having been subjected to great disturbance; and in places they have assumed a schistose character.

MASTERTON DISTRICT.

The sections examined in this district extend from Day's Hill, across Rangitauma Hill, to the Wangaehu Valley, and from Bennett's Hill to the Taueru River. These sections are very interesting and of great importance, having direct bearing on my work between Marton and the Kaimanawa Range.

Day's Hill to Rangitauma.—The rocks present in this line of section are represented by the accompanying diagram :—

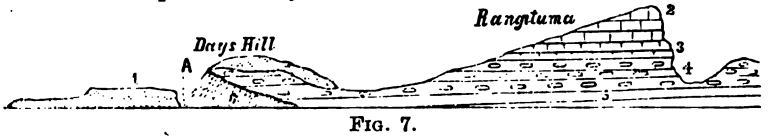


FIG. 7.

1. Gravels of plains. 2. Hard shell-limestones. 3. Calcareous sands. 4. Yellowish-blue sandy clays, with hard marlstones. 5. Blue clays. 6. Palæozoic slates and sandstones. A. Ruamahanga River.

Beds No. 1: Proceeding northwards from Masterton, the plains rise by a succession of terraces from 10ft. to 15ft. high, and on the road to Mauriceville this is particularly noticeable. The gravels forming the plains are composed of grey, green, and jasper sandstones and slates derived from the old rocks, and associated with them in places are light-coloured clays. These clays occur generally on the slopes of the hills bounding the plains, and, occurring above the level of the gravels, I considered them, at first, the remains of old high-level gravels and clays of probably lacustrine origin. However, on my return from Mokau I made a further examination of these clays at the foot of Bennett's Hill, on the road to the Taueru, where they are well exposed. They consist of material derived from the yellowish-blue clays marked 4 in the above section, and, being slope-deposits accumulated during a period of rapid denudation, may be even of more recent origin than the plains. They have every appearance of recent slope-deposits, and, as far as my own observations went at the Rangitauma, Wangaehu, and Taueru Valleys, they always occur at the foot of slopes that are occupied by Beds No. 4, and never where the shell-limestone or calcareous sands form the high ground.

Beds No. 2: In the foregoing section the top of Rangitauma, which attains a height of 2,000ft. above the sea, is occupied by these beds. It is a hard limestone, composed entirely of broken shells. In the lower beds it is difficult to distinguish what the shells are; but in the upper beds, at the top of the hill near the trig. signal, the shells are better preserved. It is composed of

broken Balanus, and is similar in every respect to the Balanus limestone which I have already described as occurring on the slopes of the Kaimanawa Range, at an altitude of 3,200ft. Besides Balanus may be found an occasional *Pecten convexus*, *Ostrea edulis* (?), *Anomia undata*, and, but rarely, *Waldheimia lenticularis*. With the exception of the latter, these are the characteristic fossils of the Balanus limestone at the Kaimanawas. The thickness of this hard shell-limestone on Rangitauma is about 150ft. It strikes N.–S., and dips W. at an angle of about 15°. The dip carries the long slope, while the descent into the Wangaehu Valley is very abrupt, and the limestone capping the range presents to the Wangaehu a line of high scarp, many miles in length.

Beds No. 3: These beds lie conformably below the Balanus limestone, and are well exposed on the east side of Rangitauma in the high scarp facing the Wangaehu. They are about 150ft. thick, and consist of loose calcareous sands, with irregular masses of hard limestone laid in layers at intervals of every few feet. The sands contain a few broken shells, *Ostrea edulis* being the only one I could determine.

Beds No. 4: These beds are exposed on both sides of Rangitauma, but are most accessible for close examination on its east side, in the high scarp. They consist of yellowish-blue sandy clays, with large irregular masses of hard calcareous marlstone, and are conformably overlain by the calcareous sands (Beds No. 3). The underlying blue clays, being obscured by slope deposits, are not exposed in the Wangaehu Valley, and in consequence I was unable to determine their thickness, which, however, must be very great, as at least 400ft. is exposed in the high scarp below the calcareous sands. They do not appear to contain fossils at this place.

Bed No. 5: This is a small isolated outcrop of Palæozoic rocks at the foot of Day's Hill. In this part of its course the Ruamahanga River flows at the foot of Day's Hill, and in this patch of hard rock has cut a narrow gorge.

Bennett's Hill to Taueru.—This section is represented by the following sketch:—

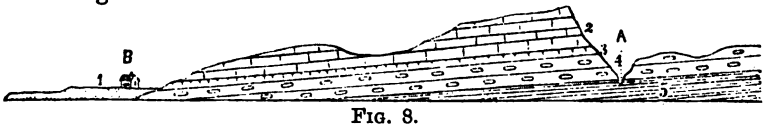


FIG. 8.

1. Recent gravels of plains. 2. Lower part of Balanus limestone. 3. Calcareous sands. 4. Yellowish-blue sandy clays, with irregular masses of hard marlstone. 5. Blue clays (Taueru clays). A. Taueru River. B. Bennett's house.

Beds Nos. 1 and 2 have already been described in the previous section, and require no further mention at present.

Beds No. 3: The calcareous sands maintain the same characters as at Rangitauma, but here contain an abundance of fossils,

of which a collection was made, including the following characteristic forms:—

Hemimactra notata, *Hutton*.
Mytilus latus, *Chemnitz*.
Cardita difficilis, *Deshayes*.
Pecten triphooki, *Zittelli*.
Pecten delicatula, *Hutton*.
Pecten convexus, *Quoy*.
Lucina dentata, *Wood*.
Dosinia grayi, *Zittel*.
Ostrea edulis (?), *Linnæus*.
Crepidula, sp. ind.
Struthiolaria papulosa, *Martyn*.
Waldheimia lenticularis, *Deshayes*.
Waldheimia patagonica, *Sowerby*.
Balanus decorus.
Fascicularia intermedia, *T.-Woods*.

Beds No. 4: The hard calcareous marlstones found in these beds at Rangitauma are more common here, and contain a few fossils:—

Pecten radiatus, *Hutton*.
Lima bullata, *Born*.
Crepidula incurva, *Zittel*.
Siphonalia nodosa, *Martyn*.

Beds No. 5: From these beds, known as the Taueru clays, the following fossils were collected:—

Solenella australis, *Quoy*.
Lima bullata, *Born*.
Pecten radiatus, *Hutton*.
Lucina dentata, *Wood*.
Pinna zealandica, *Gray*.
Crypta profunda, *Hutton*.
Trochita dilatata, *Zittel*.
Pleurotoma tuberculata, *Kirk*.
Natica ovata, *Hutton*.
Natica vitrea, *Hutton*.
Struthiolaria sulcata, *Zittel*.
Turritella rosea, *Quoy*.
Turritella tricincta, *Hutton*.
Dentalium nanum, *Hutton*.
Dentalium conicum, *Hutton*.
Balanus decorus.

TARANAKI DISTRICT.

New Plymouth to Waitara.—The rocks on this part of the coast are all of volcanic origin, or are at least composed of volcanic material, Mount Egmont being the centre of distribution. This mountain is built up of rocks that are chiefly of an acidic character; but among its earlier eruptions it has produced basic lavas, which appear to have escaped by vents situated near its base. In the fragmentary rocks around Mount Egmont and in the derived drift the proportion of basic rocks is very small, the trachytes and trachyte-porphyries largely predominating. These lavas, which are frequently of a vesicular or scoriaceous nature, are at the base of the mountain overlain by a great thickness of coarse angular volcanic breccia, through which bosses of solid rock protrude in many places. Between Hawera and Waitara most of the large streams have cut through the drift and reached this breccia. On the coast it crops out about a mile south of the Waiau, and this is probably its last appearance in this direction.

The rocks succeeding this volcanic breccia belong to the drift-formation of Dieffenbach, which includes—

1. Soft grey sandstone (trachyte).
2. Red or rusty trachyte sands.
3. Red and yellow sands and clays.
4. Gravels and conglomerates.

Bed No. 1 occurs in the vicinity of New Plymouth, and is well seen near the railway-station.

Beds Nos. 2, 3, and 4 are largely developed along the coast as far as Pukearuhe, and again appear at the north end of the White Cliffs, and extend to the Mokau. The gravels at the base of the drift are associated with a bed of lignite of variable thickness and quantities of drift-timber, evidently obtained from an old submerged forest, of which traces can still be seen.

Waitara to Mokau.—From Waitara northwards the trachyte sands and gravels with lignite and drift-timber continue to form the sea-cliffs for many miles, and there is no appearance of older rocks till a small creek, about a mile south of the Waiau, is reached. Here the volcanic series rests unconformably on an argillaceous pebbly conglomerate which contains fossils in great abundance. This bed is followed by blue sandy clays, the section at this place exposing the following beds in descending order :—

1. Volcanic soil.
2. Red and yellow sands and clays, with ironsand.
3. Gravels with lignite.
4. Gritty sands and yellow clays.
5. Argillaceous pebbly conglomerate.
6. Blue sandy clays.

Bed No. 5 is composed of quartz and sandstone pebbles, with hard concretionary nodules, and these, where there is an increase of calcareous matter, unite into regular beds. In its upper part it is frequently decomposed, and the gravels are then quarried for road-metal. The following fossils were collected from this bed at the Onaira :—

Pectunculus laticostatus, *Zittel.*
Lucina divaricata, *Lamarck.*
Ostrea, sp. ind.
Mactra æquilatera, *Deshayes.*
Venus mesodesma, *Quoy.*
Venus stuchburyi, *Gray.*
Zenatia acinaces, *Quoy.*
Cyclina dispar, *Hutton.*
Mytilicardia excavata, *Deshayes.*
Solenella australis, *Quoy.*
Dosinia grayi, *Zittel.*
Tellina deltoidalis, *Lamarck.*
Turritella rosea, *Quoy.*
Turritella tricincta, *Hutton.*
Cominella maculata, var. B, *Martyn.*
Ancillaria australis, *Sowerby.*
Buccinum robinsoni, *Zittel.*
Natica vitrea, *Hutton.*
Natica ovata, *Hutton.*
Struthiolaria tuberculata, *Hutton.*
Crepidula incurva, *Zittel.*
Cassidaria sulcata, *Hutton.*
Dentalium nanum, *Hutton.*
Dentalium ecostatum, *Kirk.*
Dentalium giganteum, *Sowerby.*

The underlying blue clays continue to the White Cliffs, where they are underlain by a coarse gritty argillaceous bed, about 2ft. thick, with broken shells and concretionary nodules. From the blue clays the following forms were collected :—

Solenella australis, *Quoy.*
Nucula nitidula, *Adams.*
Cardium striatulum, *Sowerby.*
Dentalium giganteum, *Sowerby.*
Buccinum robinsoni, *Zittel.*
Cassidaria sulcata, *Hutton.*
Pleurotoma tuberculata, *Kirk.*

Crustacean remains are common in the blue clays.

The argillaceous grit-bed is underlain conformably by thin-bedded blue clays and sands, which contain large numbers of concretionary nodules, generally laid in layers. These are underlain by blue clays, but towards the north end of the White Cliffs the

thin-bedded strata again come in, and continue along the coast almost to the Tongapourutu, where they are underlain by heavy-bedded green and brown sandstones with thin layers of clay between them. These continue to the Kawau Creek, where they lie conformably on dark-blue crumbling marly clays, which extend to the mouth of the Mokau. The whole of these beds dip about S.W. at very low angles.

Mokau to Wairere Falls.—Underlying the dark-blue marly clays at the mouth of the Mokau come thin-bedded blue tufaceous clays and greensands, with thin bands of hard marlstones and concretions. These are succeeded by brown sandstones, which at Patokatoka Creek, about four miles from the mouth of the river, are followed by a limestone band about 60ft. thick. This limestone is composed chiefly of comminuted echinoderms, and in parts it becomes coarse and gritty. It also contains an abundance of Foraminifera, which mostly belong to the genus Amphistegina, and closely resemble *A. campbelli*, Farrer, which is very plentiful in the greensandstone of Orakei Bay.* It is underlain by dark marly greensands, which are often gritty, and contain fossils in great abundance, of which the following were collected :—

Cytherea acuminata, *Hutton.*
Pecten hochstetteri, *Zittel.*
Lima colorata, *Hutton.*
Pectunculus globosus, *Hutton.*
Ostrea, sp. ind.
Pleurotoma sulcata, *Hutton.*
Ancillaria hebera, *Hutton.*
Ancillaria australis (?), *Sowerby.*
Flabellum corbiscula, *Ten.-Woods.*
Flabellum circulare, *Ten.-Woods.*

These dark marly greensands, which generally weather brown, continue to the Panirau River, and, rising to the north-east, form narrow rugged ranges with steep scarp-faces. The limestone, which occurs at water-level at Patokatoka, is seen at Mangatawa about 200ft. above the river, and at several places between these creeks can be traced in the steep scarps of the low ranges that extend towards the Awakino River. The section from the mouth of the Mokau to the coal-mine is shown in the accompanying sketch :—

FIG. 9.

1. Red trachyte-sands, clays, and gravels. 2. Dark marly clays and greensands. 3. Foraminiferous limestone. 4. Greensands and dark marly clays, with coal-seams. A. Patokatoka. B. Mangatawa. C. Coal-mine.

About seven miles below the junction of the Panirau the greensands contain several seams of coal varying from 2ft. to 8ft. in thickness. At Mangangarongaro Creek three seams are exposed; and about a mile up the Mangakawhia four seams crop out in a sandstone face, their thickness in descending order being 2½ft., 7½ft., 3ft., and 8ft. About a mile farther up the Mokau

* "Reise der 'Novara,'" Geologischer Theil I., Band II., p. 84.

two more seams are exposed in the bank of the river, their thickness being 5ft. and 5½ft. respectively.

Some two years ago these seams were worked by a Mr. Stockman, but on account of the obstruction of the Native owners of the land very little was done to develop the coal. From what I could learn, the total output of this mine was about a hundred tons of coal, which is said to be equal to the Grey coal for steaming purposes.

Several parties hold Native leases of coal-areas in the Mokau; but the New Plymouth Coal-mining Company are the only one working their coal at present. Their lease is situated on the north side of the river, and extends from the Mangakawhia to the Mangangarongaro, having a river frontage of about a mile and a half, with coal showing for most of the distance. The mouth of their main drive, which is about 150ft. long, is situated about 3 chains from the Mokau River, on the Mangangarongaro Creek. The coal is conveyed from the mine to a shoot on the bank of the Mokau by means of a wooden tramway. The shoot is capable of holding about twenty-five tons of coal, and is periodically emptied by the steamer "Waitara," which, however, calls at such long intervals that the four men employed in the mine are engaged most of their time in surface-works, such as bush-felling, &c. The Government has just completed snagging the river as far as the rapids at Mangakawhia, and steamers of light draught find no difficulty in getting up to the mine, a fairway 14ft. wide having been cleared the whole distance.

At the time of my visit about 800 tons of coal had been put out of this mine, and now that the river is cleared it is, I believe, the intention of the company to largely increase the output, by commencing operations on a larger scale. So far, the chief drawback to the development of the mine has been the uncertainty of the "Waitara's" movements, that steamer being only under contract to take coal from the Mokau when not occupied towing, &c. The directors intend to increase the number of men in the mine and charter a steamer for their own use, and thus insure a constant supply of this coal, for which there appears to be a good market at New Plymouth.

The seam this company are working is 7ft. 6in. thick, but is divided by a hard shale-band 1ft. 6in. thick, which greatly increases the cost of output. This is one of the four seams seen in the sandstone-face in the Mangakawhia Creek a mile farther up the river. At this place the shale parting is only 7in. thick, which shows that it is thinning out on the rise. The coal is exceedingly friable, and will not stand much handling.

Opposite this lease, on the south bank of the river, the Auckland Coal-mining Company have their lease; but, as most of the coal is below water-level, no attempt has been made to work it.

The coal-seams in the Mokau lie very flat, and rise to the

north-north-east into sound dry ground, and, with a deep water-channel to the outcrop, offer exceptional facilities for working to advantage.

The roof of the coal in the New Plymouth Company's mine is a hard greensand, which stands well in narrow drives; but wide chambers or galleries should not be opened without supports. At the time of my visit the large chamber at the end of the main drive in this mine was entirely without timber or supports, and the roof had a very perceptible bulge, which is a continual source of danger to the men working in the mine.

The coal greensands are not always uniform in character, being sometimes slightly micaceous, and both above and below the coal they are frequently interbedded with dark marly clays which contain in many cases numerous calcareous concretions that contain fossils. In the dark marly clay-bands or beds above the coal-seam being worked fossils are very abundant, and a large collection was made at the coal-mine, of which the following forms have been identified:—

Crassatella obesa, *Adams.*
Panopæa worthingtoni, *Hutton.*
Limopsis zealandica, *Hutton.*
Lima bullata (?), *Born.*
Psammobia, sp. ind.
Pecten hochstetteri, *Zittel.*
Pecten, sp. ind.
Dosinia grayi, *Zittel.*
Tellina deltoidalis, *Lamarck.*
Zenatia, sp. ind.
Leda, sp. ind.
Nucula, sp. ind.
Cytherea acuminata, *Hutton.*
Cardium multiradiatum, *Sowb.*
Buccinum robinsoni, *Zittel.*
Pleurotoma trailli, *Hutton.*
Conus trailli, *Hutton.*
Trochita dilatata, *Zittel.*
Trochita alta, *Hutton.*
Anthora, sp. ind.
Natica darwinii, *Hutton.*
Turritella, sp. ind.
Crypta profunda, *Hutton.*
Ancillaria lata, *Hutton.*
Cylichna striata, *Hutton.*
Nassa socialis, *Hutton.*
Placunanomia, sp. ind.
Voluta, sp. ind.

This collection embraces over a hundred species, of which 4 or 5 per cent. can probably be referred to recent forms.

Continuing the section up the river from the Panirau Junction, the next rocks met with are blue sandy clays with numerous bands of hard blue marlstone, often 2ft. or 3ft. thick. These underlie the greensands conformably, and continue to the mouth of the Mangatakiora Creek, above six miles above the junction of the Panirau. Above this the section appears to be repeated, the beds forming a flat anticline.

Near Mangatakiora Creek the greensands and dark marly clays (coal-beds) again appear, lying very flat. They extend to Totoro, where they are followed by the limestone, which is here rather flaggy or tabular, and coarse in character. It is composed of broken echinoderms and shells, of which a large thick oyster, probably *Ostrea wullerstorfi*, Zittel, is the most plentiful and best-preserved.

At the Mokauiti the dark-blue marly clays forming the upper part of the greensands lie on the Palæozoic sandstones, and at the

present ford at the Wairere Falls the limestone overlaps the old rocks. I was informed by Mr. Patterson, of the snagging party in the Lower Mokau, that a 2ft. seam of good coal crops out in the high sandstone hill behind the Native settlement Te Hura, on the Mokauiti, and is again seen on the north side of the river on the face of a high hill called Taumatine, which rises to a height of 1,560ft. above the sea. North and east of this the country is covered by a great thickness of decomposing trachyte tufa, which is generally distinguished by open fern-land of poor quality. The old rocks at the Wairere Falls, at the Rangikohu, and at the south side of the Mokauiti are grey siliceous sandstones, very much jointed and shattered, and intersected by numerous white powdery veins. In every respect they are very similar to the sandstones in the neighbourhood of Wellington.

The following section is intended to represent the section from the Mangatakiora to the Wairere Falls:—

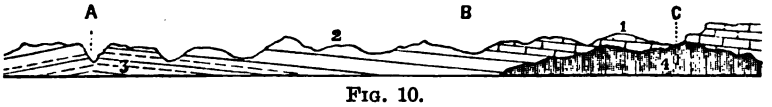


FIG. 10.

A. Mangatakiora. B. Totoro. C. Wairere Falls. 1. Limestone. 2. Dark-blue marly clays and greensands, with coal-seams. 3. Blue sandy clays, with hard marlstone bands. 4. Palæozoic sandstones.

From the sea to Kawakawa, a distance of sixty miles, the Mokau passes through a very rough, broken bush-covered country, divided by numberless streams into a great many steep narrow ridges from 500ft. to 1,500ft. high. The bush is of little value, consisting chiefly of tawa and black-birch, with a few puriri and rimu thinly scattered throughout. The open land around Totoro is of very fair quality, but it is of small extent and rather broken.

The following is the result of an analysis of two samples of coal from the New Plymouth Coal-mining Company's mine. No. (1) is from the top of the seam, and No. (2) from below the shale parting—Laboratory No. 4260:—

	No. (1).	No. (2).
Fixed carbon	46·17	47·58
Hydro-carbon	34·15	36·05
Water	13·92	12·79
Ash	5·76	3·58
	100·00	100·00

Evaporative power: No. (1), 6lb.; No. (2), 6·18lb.

REMARKS.—These are glance-coals, are tender, and do not cake; burn well, leaving a white ash. They have the appearance of bituminous coals, but are largely hydrous.—W. SKEY, Analyst.

WANGANUI DISTRICT.

Landguard Bluff.—The beds at this place are lying almost flat, and are represented by the following section:—

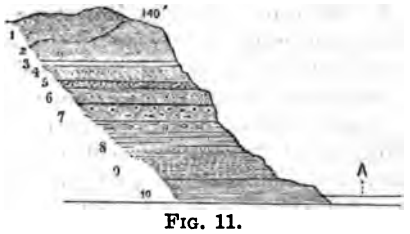


FIG. 11.

A. Wanganui River. 1. Blown sands. 2. Brown sands, loose, slightly ferruginous, 30ft. 3. White clay, soft, 2ft. 4. Brown sands, loose, micaceous, 15ft. 5. Gritty shell-bed, with trachyte pebbles, 4ft. 6. Yellow sands, loose, micaceous, with thin irregular layers of trachyte gravels, 7ft. 7. Rusty trachyte gravels and sands, false-bedded, often cemented hard by iron peroxide, 12ft. 8. Yellow sands and clays, with layers of trachyte grits, thin-bedded, slightly ferruginous at upper surface, with pumice in grits, 30ft. 9. Yellowish-brown sands, loose, micaceous, with marine shells in abundance, 20ft. 10. Pale greensands, loose, no shells, 20ft.

Following the cliffs towards the mouth of the river, the shell-bed above the trachyte gravels thins out altogether, and the beds of yellowish sand increase in thickness to almost the entire exclusion of the gravels, which, however, a few chains farther west again assume their normal thickness of about 12ft. About 5 chains from the extreme west end of Landguard Bluff a fault extends across the strike of the beds. The gravel-bed which occupies a position about the middle part of the cliff is faulted down to water-level, the displacement being about 50ft. The following longitudinal section along the strike shows the position of the fault :—

FIG. 12.

Landguard Bluff, showing fault.

On the west side of the fault, about 15ft. above the trachyte gravels, there occurs a bed of impure lignite, apparently about 3ft. thick. It does not continue for any distance.

Putiki Cliff.—Between Putiki Pa and the Wanganui Bridge the beds are considerably disturbed, and dip to S.E. at an angle of 45°. The section exposed here is as follows :—

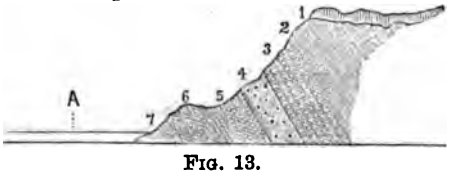


FIG. 13.

A. Wanganui River. 1. Superficial slope-deposit. 2. Brown sand, loose, slightly ferruginous, 15ft. 3. Fine sands, silts, and clays, yellow and white, 25ft. 4. Red cement-gravel, 12ft. 5. Yellow sands and clays, micaceous, thin-bedded, 15ft. 6. Blue clays with marine shells, 8ft. 7. Brown sands, loose, micaceous, 20ft.

The gravels of Bed No. 4 consist chiefly of volcanic material, mostly of an acidic character; but pebbles of white quartz, grey sandstones, and dark slaty shales are not uncommon, and fragments of pumice are by no means rare.

Shakespeare Cliff.—At this place the base of the cliff is occupied by blue sandy clays, with shells in great abundance, especially in their upper part. They are overlain by thin-bedded yellow clays and sands, and shell-beds, which are succeeded by the red cement-gravel beds, which are in their turn overlain by yellow sands and clays.

The beds are generally so much false-bedded that many sections, varying slightly in detail, may be obtained in different parts of this line of cliffs.

A cross-section of Shakespeare Cliff, at the end nearest to the bridge, is shown below:—

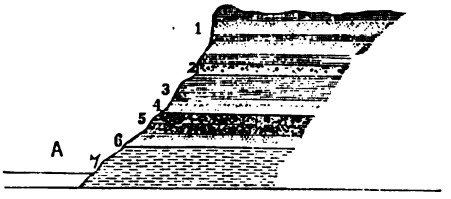


FIG. 14.

A. Wanganui River. 1. Yellow sands and clays, 100ft. 2. Rusty cement-gravels and sands, 5ft. 3. Thin-bedded yellow sands and clays, with marine shells, 12ft. 4. Loose brown sands, with thin layers of yellow clay, 12ft. 5. Gritty shell-bed, 4ft. 6. Yellowish-brown sands, loose, 12ft. 7. Blue sandy clays, 60ft.

These beds are lying very flat, but have a perceptible dip to S.S.W.

Kaimatera Cliff.—A section of the north end of this line of cliffs is shown in the following diagram:—

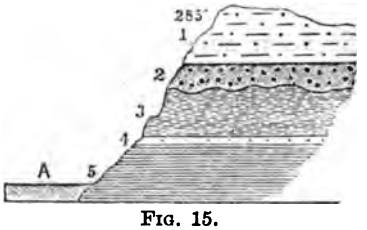


FIG. 15.

A. Wanganui River. 1. Yellow micaceous sands and clays, with thin ferruginous veins, 80ft. 2. Rusty cement-gravels and sands, 35ft. 3. Thin-bedded yellow sands and clays, 60ft. 4. Thin-bedded clays and pumice-sands and grits, with marine shells, 15ft. 5. Thin-bedded yellow clays and sands, 95ft.

The beds forming this cliff are much false-bedded, presenting in many places what might be taken for decided unconformities, which, however, are easily traceable to this cause.

The rusty cements and yellow sands and clays, Beds Nos. 1 and 2 in the above sketch, are quite unconformable to the under-

lying thin-bedded yellow sands and clays, and proceeding up the Wanganui they are found lying successively on Beds Nos. 4 and 5.

The marine beds at Kaimatera Cliff dip S.S.W. at a very low angle, and pass under the Shakespeare Cliff beds.

Kaiwaiki Quarries.—The Kaiwaiki quarries, where the material for the Wanganui harbour-works is obtained, are situated on the river about fourteen miles above the town. The hard, gritty cement shell-beds, or limestones as they are sometimes called, occur at wide intervals in loose, brown micaceous sands, and vary from a few inches to 50ft. in thickness. The bedding is very flat, and the shell-beds are exposed in high escarpments along the banks of the river for several miles, and have been quarried at all available points from water-level to 500ft. above the river.

About 10 chains below the quarry wharf the following section is exposed:—

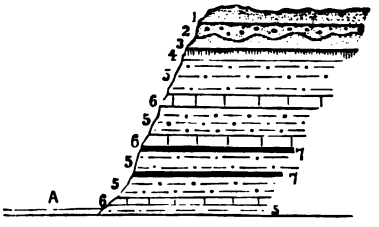


FIG. 16.

A. Wanganui River. 1. Ferruginous sandy clays, 50ft. 2. Rusty trachyte cement-gravels, 20ft. 3. Brown ferruginous sands, 15ft. 4. Hard shell-bed, 10ft. 5. Yellowish-brown micaceous sands, 410ft. 6. Hard limestone beds, 65ft. 7. Thin-bedded brown sands and light-coloured clays, 10ft.

A large number of shells were collected from these beds, most of which occur in the Nukumaru limestone. Among these I found the femur of a bird, ·7in. long and very strong and heavy for its length.

At Raorakia, about four miles farther up the river, the brown micaceous sands are seen lying on blue clays with concretionary nodules, which alternate with yellowish-blue sandy clays and brown micaceous sandstones. In the latter, at Parakino, occurs a shell-bed 25ft. or 30ft. thick, of which the most characteristic shell is *Ostrea ingens*. Proceeding up the river the beds are very uniform and undisturbed, rising to N.N.W. at an angle of 2½°. Near Corinth the brown sandstones are occasionally interbedded with thick beds of blue clays with layers of Septaria, which frequently unite into continuous beds of marlstone. These hard bands form flat ledges on the banks of the river. At Corinth the blue clays with Septaria occupy the greater part of the cliffs bounding the river, and continue north about a mile beyond this, and are succeeded by heavy-banded blue clays and brown sandstones, which are well seen near the rapids at Ruapirau. At Karatea the blue clays contain a few minute shells, and at the

same place the brown sandstones contain a large number of irregular masses of more calcareous material.

About a mile and a half past Karatea the heavy-bedded strata are succeeded by blue clays with Septaria, which continue to Jerusalem, where the heavy-bedded rocks again come in. These continue about half-way to Pipiriki, and are succeeded by yellowish-blue sandy clays, which are in a short distance followed by blue clays. In the road-cutting at Pipiriki I collected the following fossils in the clays: *Solenella australis, Mytilus edulis, Nucula nitidula, Balanus decorus,* a Trochus, and several small bivalves.

Wanganui Heads to Kai-iwi.—The first two miles north of the heads is occupied by sandhills; beyond this a line of cliffs bounds the shore. The cliffs are formed of blue clays, capped by a heavy deposit of drift, consisting of red trachyte-gravels, yellow sands and clays, while at its base there is generally a quantity of drift-timber and a seam of impure lignite.

In many places along the coast the blue clays have been excavated into deep caverns, while numerous outliers of every conceivable shape and design stand out from the cliffs, being often connected with the mainland by archways or bridges of the same material. The section from the commencement of the cliff to the Kai-iwi Stream is illustrated by the following sketch:—

FIG. 17.

1. Blown sands. 2. Yellow sands and clays, with lignite and drift-timber. 3. Sands and clays, with marine shells. 4. Blue clays. 5. Kai-iwi clays. 6. Thin-bedded dark clays and argillaceous sands. A. Kai-iwi Stream.

The section exposed at the south end of the cliffs shown in the above sketch is the same as that exposed at Shakespeare Cliff. Bed No. 3 is apparently identical with the upper sandy beds of that place, and Bed No. 4 with the lower blue clays, containing all the characteristic fossils of that horizon. The shells of Bed No. 4, which occur in great abundance and usually laid in layers, are often cemented into hard tabular masses with an argillaceous matrix. In the clays below the heaviest of the shell-beds I found a small waterworn fragment of pumice, thus fully bearing out Mr. Drew's statement that pumice had been found in Shakespeare Cliff.

The Kai-iwi blue clays are quite distinct from Bed No. 4, and contain a large number of shells, which are generally disseminated throughout their whole thickness. About ninety-five species were collected from this horizon, the most characteristic being,—

Solenella australis, *Quoy.*
Cardium striatulum, *Sowerby.*
Tellina alba, *Quoy.*
Pecten radiatus, *Hutton.*
Dosinia grayi, *Zittel.*
Myodora striata, *Quoy.*
Nucula nitidula, *Adams.*
Pinna zealandica, *Gray.*
Mysia zealandica, *Gray.*
Mactra scapellum, *Deshayes.*
Leda concinna, *Adams.*
Zenatia acinaces, *Quoy.*
Pectunculus striatularis, *Lamarck.*
Turbo granosus, *Martyn.*
Ancillaria australis, *Sowb.*
Turritella rosea, *Quoy.*
Turritella tricincta, *Hutton.*
Turritella pagoda, *Reeve.*
Turritella vittata, *Hutton.*
Natica zealandica, *Quoy.*
Murex zealandicus, *Quoy.*
Murex octagonus, *Quoy.*
Imperator imperalis, *Chemnitz.*
Scalaria zelebori, *Frauenfeld.*
Pleurotoma tuberculata, *Kirk.*
Dentalium nanum, *Hutton.*
Dentalium ecostatum, *Kirk.*
Dentalium conicum, *Hutton.*
Terebratella cruenta, *Dillwyn.*
Terebratella rubicunda, *Soland.*
Rhynchonella nigricans, *Sowb.*
Arachnoides zealandiæ, *Gray.*

Kai-iwi to Waitotara Heads.—The distance from Kai-iwi Stream to Okehu is somewhat less than two miles; from Okehu to Butler's Creek, three miles; from Butler's Creek to Nukumaru Beach, about three miles; and from there to the Waitotara Heads, about eight miles.

After passing Kai-iwi Stream the coast trends almost due west, and on account of the low dip the underlying beds are but slowly developed, and the lower beds at that place (Beds Nos. 5 and 6) continue to Okehu Creek before they run out.

The section exposed in this part of the coast may be best understood by reference to the following sketch:—

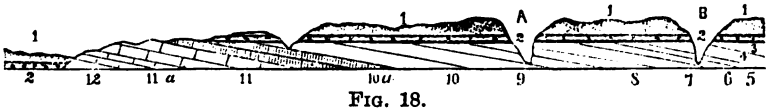


FIG. 18.

A. Butler's Creek. B. Okehu Stream. 1. Blown sand. 2. Yellow sands and clays, and rusty trachyte gravels with lignite and drift-timber. 3. Kai-iwi blue clays. 4. Thin-bedded blue clays and brown sands. 5. Blue clays, sometimes thin-bedded. 6. Gritty shell-bed in blue clays. 7. Greenish-blue clays, with shell-beds and a seam of lignite. 8. Sandy shell-beds, with hard shell-cement (or limestone-bands). 9. Brown sands. 10. Yellowish sandy clays. 10*a*. Loose sandy shell-beds, with numerous hard flaggy argillaceous limestone-bands, which extend a considerable distance to seaward, forming flat rocky shoals (Rotella beds). 11. Coarse flaggy shell-limestone (Nukumaru limestone). 11*a*. Yellowish-brown micaceous sandstones, with shell-beds (coralline beds). 12. Yellowish-blue sandy clays.

Between the Kai-iwi and Okehu there occurs a large quantity of pumice in the blue clays of Bed No. 3, usually in blocks from 6in. to 1ft. in diameter, which are distributed throughout a layer of clay about 6ft. thick.

Beds No. 4: These beds consist of very thin-bedded blue clays and brown sands, and, by the removal of the sandy layers, the clays, on weathered surfaces, stand out as thin folia. Their total thickness is about 30ft., but in the bottom 5ft. the brown-sand layers are replaced by quartz-sands and pumice-grits, with larger fragments of pumice scattered throughout, in precisely the same manner as seen at Kaimatera Cliff, and in the railway-cuttings between Aromoho and Brunswick Stations.

Beds No. 7: These clays are about 50ft. thick, and pass into argillaceous greensands, which contain a seam of lignite about 2½ft. thick. Above the lignite there occurs a thin bed of shells, consisting entirely of *Venus stuchburyi*.

Beds No. 8: These are loose sandy shell-beds, interbedded, at short intervals, with flaggy shell, cement, or limestone bands, which are very irregular, and seldom continuous for any distance. They are well exposed at the old flax-mill near the bottom of Butler's Creek, and in the ballast-pits between Kai-iwi and Okehu stations. A large collection of shells was made from these beds at the latter place, embracing about eighty species, of which the following forms are the most characteristic:—

Venus stuchburyi. *Gray.*
Venus mesodesma, *Quoy.*
Arca decussata, *Sowerby.*
Pectunculus laticostatus, *Quoy.*
Mytilicardia excavata, *Deshayes.*
Tellina disculus, *Deshayes.*
Ostrea edulis (?), *Linnæus.*
Ostrea nelsoniana (?), *Zittel.*
Barnea similis, *Gray.*
Cardita difficilis, *Deshayes.*
Lutraria solida, *Hutton.*
Anomia undata, *Hutton.*
Cardium multiradiatum, *Hutton.*
Lima colorata, *Hutton.*
Mesodesma spissa, *Reeve.*
Astarte australis, *Hutton.*
Rotella zealandica, *Hombron.*
Anthora tiarata, *Quoy.*
Murex octagonus, *Quoy.*
Cerithium cancellatum, *Hutton.*
Crepidula incurva, *Zittel.*
Crepidula contorta, *Quoy.*
Crepidula costata, *Sowerby.*
Trochita novæ-zealandiæ, *Lesson.*
Trochita dilatata, *Zittel.*
Voluta gracilis, *Swainson.*
Amphibola avellana, *Chemnitz.*
Natica ovata, *Hutton.*
Ancillaria australis, *Sowerby.*
Turbo granosus, *Lamarck.*
Dentalium conicum, *Hutton.*

In the loose sandy portions of these beds large fragments of pumice are common.

Beds No. 10*a*: These consist of loose sands and blue sandy clays interbedded with numerous hard argillaceous limestone bands. They contain the following fossils:—

Lutraria solida, *Hutton.*
Mesodesma grandis, *Hutton.*
Ostrea edulis (?), *Linnæus.*
Ostrea nelsoniana, *Zittel.*
Hemimactra notata, *Hutton.*
Dosinia subrosea, *Gray.*
Venus yatei, *Gray.*
Pecten radiatus, *Hutton.*
Pinna zealandica, *Gray.*
Anomia undata, *Hutton.*
Perna quadrata.
Natica zealandica, *Quoy.*
Rotella zealandica, *Hombron.*
Turritella rosea, *Quoy.*
Voluta pacifica, *Lamarck.*
Voluta gracilis, *Swainson.*
Arachnoides zealandiæ, *Gray.*

Rotella zealandica occurs in large numbers in these beds, which on this account have been called the Rotella beds.

Bed No. 11: This is a coarse flaggy shell-limestone, which is first seen on the coast, at Nukumaru beach. It is composed of shells, of which fifty-eight species were collected, and well-rounded pebbles of quartz, grey sandstones, and dark slaty shales. I could find no volcanic rocks in this limestone. Its thickness is about 250ft., and it is often false-bedded. The following is a list of the characteristic forms collected at Nukumaru beach:—

Lutraria solida, *Hutton.*
Zenatia acinaces, *Quoy.*
Hemimactra notata, *Hutton.*
Pectunculus laticostatus, *Quoy.*
Cardita difficilis, *Deshayes.*
Mytilus latus, *Chemnitz.*
Modiola australis, *Gray.*
Anomia alectus, *Gray.*
Ostrea edulis (?), *Linnæus.*
Ostrea nelsoniana, *Zittel.*
Venus stuchburyi, *Gray.*
Venus mesodesma, *Quoy.*
Solenella australis, *Quoy.*
Pecten triphooki (rare), *Zittel.*
Pecten convexus, *Quoy.*
Pecten laticostatus, *Gray.*
Pecten radiatus, *Hutton.*
Perna quadrata.
Dosinia grayi, *Zittel.*
Tapes intermedia, *Quoy.*
Myodora striata, *Quoy.*
Pinna zealandica, *Gray.*
Lima bullata, *Born.*
Lima colorata (?), *Hutton.*
Astarte australis, *Hutton.*
Venus oblonga, *Hanley.*
Tellina deltoidalis, *Lamarck.*
Panopæa zealandica, *Quoy.*
Rotella zealandica, *Hombron.*
Anthora tiarata, *Quoy.*
Turbo granosus, *Martyn.*
Turritella rosea, *Quoy.*
Ancillaria australis, *Sowb.*
Trochita novæ-zealandiæ, *Lesson.*
Crepidula monoxyla, *Lesson.*
Voluta pacifica, *Lamarck.*
Scalaria zelebori, *Frauenfeld.*
Natica ovata, *Hutton.*
Crenella impacta, *Hermann.*
Lucina dentata, *Wood.*
Waldheimia lenticularis, *Deshayes.*
Balanus decorus.
Arachnoides zealandiæ, *Gray.*
Corals.

Like all the beds in this part of the district this limestone rises to N.N.W. at very low angles. It has a surface exposure of about ten square miles, its sea-frontage being not less than three miles. In places it approaches within 50 or 60 chains of the railway-line, from which it is separated by a strip of low sandhills. A short siding might easily be constructed to reach the limestone area, which is perfectly free of all superficial deposits, and consequently in opening quarries no stripping would be necessary.

The great extension of this limestone on the coast between Waitotara and Nukumaru cannot fail to be of immense economic value to the Wanganui district, where road-metal, railway-ballast, building-stone, and material for harbour-works are so scarce; and at present the two last are only obtainable from the Kaiwaiki quarries at great cost on account of the distance and amount of handling. The inaccessible positions of the hard limestone-bands at these quarries, and the great amount of necessary stripping, also add considerably to the cost of production.

At Nukumaru the amount of material is practically unlimited, and, being easily accessible to the railway-line, should be supplied at a very low rate. The land occupied by the Nukumaru limestone is at present Crown land, and it would be a serious loss to this district if it were suffered to fall into private hands.

The annexed section shows the surface exposure of the limestone, and its extension from the coast to the railway-line, a distance of about three miles:—

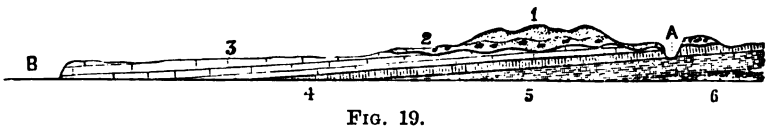


FIG. 19.

1. Blown sands. 2. Yellow clays, sands, and gravels of drift. 3. Nukumaru limestone. 4. Brown micaceous sandstones, with *Ostrea ingens*. 5. Yellowish-blue sandy clays. 6. Blue clays, with concretionary nodules. A. Railway cutting. B. Sea.

The Nukumaru limestone occurs at sea-level, near the mouth of the Waitotara River, and slowly rises inland, occupying the tops of all the higher bush-clad ranges towards the sources of the Kai-iwi, Waitotara, Whenuakua, and Patea Rivers. In a similar manner it rises from water-level near Parakino, and forms a crust on the flat-topped ranges in the Upper Wanganui and Rangitikei districts.

Beds No. 11*a*: The characteristic shell of these beds is *Ostrea ingens*, which occurs in great abundance in a shell-bed near the mouth of the Waitotara River, opposite Wilkie's Farm. From the shell-bed there the following fossils were collected:—

Ostrea ingens, *Zittel.*
Ostrea edulis (?), *Linnæus.*
Ostrea glomerata, *Gould.*
Ostrea corrugata, *Hutton.*
Pecten radiatus, *Hutton.*
Pecten athleta, *Zittel.*
Placunanomia incisura, *Hutton.*
Anomia undata, *Hutton.*
Turritella rosea, *Quoy.*
Turritella tricincta, *Hutton.*
Crepidula monoxyla, *Lesson.*
Waldheimia lenticularis, *Desh.*
Terebratella rubicunda, *Sol.*
Fascicularia intermedia, *Tenison-Woods.*
Cylindropora spongiosa, *Tenison-Woods.*
Cladocora dubia, *Tenison-Woods.*
Amphelia, sp. (?).
Reteropora, sp. (?).

The shell-bed near Wilkie's Farm, which is about 50ft. thick, is chiefly characterized by the large number of oysters (*Ostrea ingens*) and corals which it contains.

Waitotara to Patea.—From the mouth of the Waitotara the coast trends more to the north, and often nearly parallel to the strike of the Tertiary strata, and by following along the beach to Patea the sequence of beds underlying the Waitotara limestone is gradually developed at water-level.

At the Native settlement below Wilkie's farm, situated about two miles from the beach, the bed of the Waitotara is studded with the upright stumps of an old forest, which, on both banks of the river, is overlain by the yellow micaceous sands and clays of the drift formation. There are many other evidences of the existence of a submerged forest between Wanganui and Patea, and Taranaki and Mokau, which will be dealt with further on.

The first three miles north of the heads the coast-line is occupied by low sandhills and quicksands; and, beyond this, the beach is bounded by steep cliffs, which extend to Patea. In this part the sandhills encroach many miles inland, and it is only on the coast that the Tertiary rocks can be examined.

At the point where these rocks first appear, north of the Waitotara Heads, the strata have been more disturbed than elsewhere in this district, and have been faulted in the manner shown in the annexed section:—

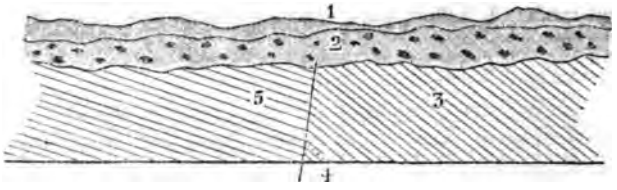


FIG. 20.

1. Blown sand. 2. Yellow sands and clays, with trachyte gravels and drift-timber at base. 3. Blue sandy clays. 4. Sandy shell-bed. 5. Blue clays, with concretions.

From Bed No. 4 the following fossils were collected:—

Cardium spatiosum, *Hutton.*
Ostrea nelsoniana, *Zittel.*
Pecten athleta, *Zittel.*
Pecten radiatus, *Hutton.*
Pecten semiplicatus, *Hutton.*
Pecten triphooki, *Zittel.*
Pecten, sp. nov.
Lucina dentata, *Wood.*
Venus yatei, *Gray.*
Venus oblonga, *Gray.*
Perna quadrata.
Pectunculus laticostatus, *Quoy.*
Panopæa zealandica, *Quoy.*
Hemimactra elongata, *Hutton.*
Cardita zealandica, *Potiez.*
Cyclina dispar, *Hutton.*
Venus mesodesma, *Quoy.*
Ancillaria australis, *Sowb.*
Natica vitrea, *Hutton.*
Natica ovata, *Hutton.*
Natica zealandica, *Quoy.*
Dentalium conicum, *Hutton.*

The fossils obtained from Bed No. 5 are,—

Ostrea ingens, *Zittel.*
Ostrea nelsoniana, *Zittel.*
Lucina dentata, *Wood.*
Modiola australis, *Gray.*
Zenatia acinaces, *Quoy.*
Mysia globularis, *Lamarck.*
Pecten radiatus, *Hutton.*
Crepidula incurva, *Zittel.*
Trochita novæ-zealandiæ, *Lesson.*
Turritella tricincta, *Hutton.*
Siphonalia nodosa, *Martyn.*
Pleurotoma sulcata, *Hutton.*
Terebratella cruenta, *Dillwyn.*

The true relation of Beds Nos. 4 and 5 is not very clear in the above section, but between the Wairoa and Whenuakura, where the same beds are exposed, the shell-bed is seen lying conformably on Bed No. 5, being separated by above 60ft. of blue clays. From this place the beds rise at a very low angle till Patea is reached, where the following section is exposed in the cliffs near the railway-line:—

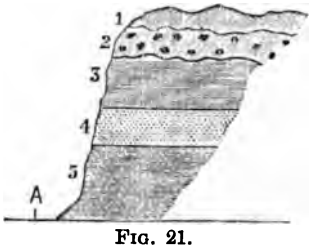


FIG. 21.

1. Blown sands. 2. Yellow sands, clays, and gravels of trachyte drift. 3. Blue clays. 4. Loose brown sands. 5. Blue clays, with fossils. A. Patea River.

The fossils obtained from Bed No. 5 are,—

Solenella australis, *Zittel.*
Pinna zealandica, *Gray.*
Nucula nitidula, *Adams.*
Struthiolaria cingulata, *Zittel.*
Fish-scales.

CLASSIFICATION.

The investigation of the geological structure of this area is attended with considerable difficulty. The dense vegetation by which, in many places, the strata are covered at the line of junction, the great denudation which they have suffered, and the absence of sections in those situations where the relative position of the rocks is involved in obscurity, present numerous, and in some instances insuperable, obstacles to accurate observation. Under such circumstances analogy must supply the place of actual observation; but, the relative position of the principal strata having been correctly ascertained, whatever errors may have originated from the above causes will relate chiefly to the geographical distribution of the strata, and cannot affect the geological deductions that may be drawn from the observations contained in the preceding pages.

The following classification of the strata in this district is that which, after much consideration, I have been led to adopt, as conformable to their order of superposition :—

Recent and Pleistocene—
- *a.* Blown sands, river-terraces, and superficial pumice deposits.
- *b.* Drift formation of Taranaki and Wanganui.

Newer Pliocene—
- *a.* Wanganui beds.
- *b.* Kai-iwi blue clays.
- *c.* Pohangina, Kaimatera, and Okehu pumice-sands.
- *d.* Butler's Creek and Okehu sandy shell-beds and brown sands, Nukumaru beach.
- *e.* Rotella beds, Nukumaru beach.

Older Pliocene—
- *a.* Nukumaru, Kaiwaiki, and Pukiori limestones.

Upper Miocene—
- *a.* Coralline series at Waitotara and Parakino.
- *b.* Patea and Pipiriki blue clays, and brown sands.
- *c.* Argillaceous pebbly shell-beds at Manganui-a-te-ao; and Oarangi, Erehwon.
- *d.* Blue clays with gritty shell-beds at Onaira; and Puketapu, Upper Wanganui.
- *e.* Blue clays at White Cliffs; and Paparoa, Upper Wanganui.

Cretaceo-tertiary—
- *a.* Tufaceous greensands and crumbling marly clays, Mokau River.
- *b.* Foraminiferous limestone, Patokatoka.
- *c.* Greensandstones and dark marly clays, with coal-seams.
- *d.* Blue sandy clays, alternating with bands of marlstone.

Carboniferous—
- *a.* Siliceous sandstones and slaty shales, Ruahine and Kaimanawa Ranges.

Volcanic—
- *a.* Volcanic tufas and agglomerates.
- *b.* Extinct volcanoes, Mounts Egmont and Ruapehu.

RECENT AND PLEISTOCENE.

Blown Sands. — These occupy a strip of country along the coast, which varies considerably in breadth. Where the coast-line is low the sands have invaded the mainland a distance of ten or twelve miles, as in the Lower Rangitikei and at Waverley; and where the shore is bounded by steep cliffs, with broken country behind, they cover but a limited area.

In the Taranaki District these sands are composed entirely of volcanic material, which south of Wanganui is gradually replaced by material of sedimentary origin, derived from the Palæozoic rocks of the Ruahine and Kaimanawa Ranges. Between Hawera and Wanganui they are highly fertile, and a large area has been reclaimed for pastoral purposes. They form a rich porous soil, which grows grasses in great luxuriance; but, being light, it is not at all suited for agricultural purposes, as the sward when once broken for cropping takes several years to recover its former condition.

River-terraces. — The river-terraces in this area are most noticeable in the upper portions of the river-courses, where the evidences of erosion are more marked than in the lower valleys. The number of terraces is commonly two or three, but sometimes as many as five or six or even a greater number may occur, as in the Upper Hautapu and Wangaehu.

By far the finest display of terraces in this area is seen at what are known as the Murimotu Plains. From Karioi, which is situated at the southern end of the plains and 2,000ft. above the sea, the country rises towards Ruapehu by a series of high broad terraces to a height of 3,500ft. above sea-level. These terrace-plains have been formed by the Wangaehu and its tributaries.

Superficial Pumice Sands and Gravels.—These occur as a very thin coating around Erehwon, but on the southern slopes of the Kaimanawas they are so plentiful as to make portions of this range utterly useless for pastoral purposes. North of this the pumice is even more widespread, and in the valley of the Waikato, before it enters Lake Taupo, terraces of pumice-gravels are exposed by the river from 75ft. to 100ft. high.

Large quantities of pumice are brought down by the Wanganui River from the west side of Tongariro, most of which is carried out to sea, and distributed along the shores of Cook Strait.

The existence of heavy deposits of pumice on the Kaimanawa Range and the high lands of Hawke's Bay has always been a difficult problem to geologists, but the recent volcanic disturbance at Tarawera, on the 10th June last, throws much light on the formation of such deposits. During the first few hours of this eruption almost two thousand square miles of country were smothered in mud, sand, dust, and other volcanic ejectamenta, and places twenty-five or thirty miles distant from the centre of activity were covered several inches deep, while in the immediate

vicinity of Tarawera and Rotomahana the mass of ejected matter is so great that the contour of the ground is quite altered, and many of the former landmarks are now obliterated.

The slopes of Ruapehu and Tongariro are covered with ejected matter; and in the valley of the Waikato, near the Poutu River, occur immense accumulations of pumice, clearly showing that volcanic eruptions of great magnitude have taken place in former times in this area. It was, no doubt, during one of these eruptions that large quantities of pumice were ejected and carried by the prevailing winds across the Kaimanawas into Hawke's Bay.

Drift Formation.—This formation is very widely distributed, and extends as a maritime belt from the Ruahine Range to the foot of Mount Egmont; and on the North Taranaki coast, from New Plymouth to the Mokau. At Kaiwaiki it occurs at an altitude of 400ft. above the sea, but at no other place has it been observed at a greater height than this.

It consists of stratified sands and clays that are usually micaceous, and of a yellow or red colour; and coarse gravels that are often cemented by iron peroxide into rusty conglomerates. Near the volcanic centre of Taranaki the gravels consist chiefly of igneous rocks, while east of the Rangitikei they are composed of siliceous sandstones and dark slaty shales.

The drift is well exposed in the cliffs between Wanganui and Patea, and a great many opportunities are presented of closely studying its character. Drift-timber and upright stumps of trees occur in most places at its base. These are covered or mixed with gravels, in which marine shells are sometimes found in small patches or irregular layers. There appears to be no regular order of superposition of the various beds of the drift. For short distances the drift-timber and gravels are absent, or more frequently appear at the top of the series, and the yellow sands and clays lie directly on the Tertiary clays or limestones.

At most places on the coast between Wanganui and Patea the Tertiary strata are but slightly inclined from a horizontal position, and where immediately succeeded by the stratified sands and clays of the drift there is no apparent unconformity between the Pleistocene and Tertiary formations. But, although at special points it is difficult to determine an unconformity, this is made quite clear by the manner in which the drift is found resting successively on the different members of the Tertiary formation. At Wanganui it lies on the upper sandy beds, and proceeding along the coast, on the rise of the beds, it may be seen resting alternately on the Kai-iwi blue clays, Okehu beds, Waitotara limestone, Whenuakura and Patea clays. On the Taranaki coast also it lies on the younger Tertiaries between the Waiau and the White Cliffs, and on the Cretaceo-tertiary strata at the Mokau.

The submerged forest already alluded to as underlying the

drift is associated with a bed of lignite of variable thickness, which is well exposed at Landguard Bluff (Fig. 12), and in many places on the coast north of Wanganui.

It is remarkable that, although the drifts extend inland a great many miles, the evidences of a submerged forest and lignite are never met with more than a mile or two from the present shore-line, and then only in low-lying areas. It would thus appear that this ancient forest flourished in a narrow belt of low, swampy land adjacent to the sea. The occurrence of irregular beds of marine shells at the base of the drift points to the existence of shallow brackish lagoons within the influence of the tide. The shells are all marine and recent, and include the following forms: *Venus stuchburyi*, *Venus mesodesma*, and *Turritella rosea*.

Referring to the more recent deposits which cover a large portion of Taranaki, Dr. Hector says, "These are Pleistocene deposits consisting of stratified gravels and sand-rock (not hard enough to be termed sandstone), with beds of lignite. This formation, which corresponds in age and stratigraphical position with certain of the auriferous gravels of the South Island, is highly charged with oxide of iron, and is readily distinguishable, forming the upper part of all the cliffs along the coast north of the Waitara, by its deep-red colour. These gravels do not extend far inland, nor to a greater altitude above the sea than 150ft., so that they must be regarded as in some way connected with an ancient coast-line; and from the circumstance that at the base of this formation in many places, and underneath the lignite-seams, there is a layer of rolled broken shells of existing species, we may infer that these gravels have been deposited in lagoons parallel with the coast-line during a gradual elevation of the land, and that they have been overtaken, as it were, by the encroachment of the sea, and exposed in the sea-cliffs after they are 80ft. or 100ft. above the present level of the tide. As, during the interval which must have elapsed, there was time for the formation of beds of lignite 8ft. to 10ft. thick, we thus have an indication of the extreme slowness with which changes of level are taking place, even in an area of such marked volcanic action as that around Mount Egmont."—(Geological Reports, 1866–67, p. 3.)

Summarising the observations relating to the Tertiary rocks in the Wanganui area, the following results are obtained: (1.) That there is no stratigraphical break in the sequence of the Tertiary strata from the lowest to the highest beds; (2) that the beds above the Nukumaru limestone are of a littoral character, and were formed on a rising surface, consequently by the gradual recession of the shore-line an apparently great thickness of strata is exposed at a slight elevation above the sea; and (3) that lower beds are exposed in the Upper Wanganui and on the Taranaki coast than in the Upper Rangitikei district.

All the beds above the Nukumaru limestone are included in the Newer Pliocene period.

Newer Pliocene—
a. Wanganui beds.
b. Kai-iwi blue clays.
c. Pohangina, Kaimatera, and Okehu pumice-beds.
d. Butler's Creek sandy shell-beds and brown sands.
e. Rotella beds, Nukumaru beach.

a. *Wanganui Beds.*—These include the upper sandy beds at Landguard Bluff, Putiki Cliff, and all the beds exposed at Shakespeare Cliff (Fig. 14). The sandy beds and underlying blue clays contain shells in great abundance, most of which belong to recent species. In his paper on "The Wanganui System," Captain Hutton says the number of species from the upper sandy beds is 156, of which 72 per cent. are recent; and from the lower blue clay 133 species, of which 77 per cent. are still living in the adjacent seas (Trans. N.Z. Inst., Vol. XVIII., p. 340).

These percentages of living species appear very low for such recent beds, and can only be accounted for by supposing that fossils from other places have been mixed with those from the sandy beds and blue clays at Wanganui.

Mr. Drew, who supplied Captain Hutton with most of his fossils from Wanganui, informed me that he only recognised two distinct horizons in that district, which are represented by the upper sandy and lower blue-clay beds at Shakespeare Cliff. He therefore considered that all the fossils from loose sandy strata, such as the Okehu beds, belonged to the upper sandy beds; and those from blue clays, such as at Kai-iwi and Patea, to the lower blue clays.

Captain Hutton is apparently of the same opinion as Mr. Drew with regard to the sequence of the beds in this district, and considers the section of blue clays, red and yellow sands, and gravels exposed on the coast at Patea very similar to that at Wanganui (Trans. N.Z. Inst., Vol. XVIII., p. 340).

It would appear Mr. Buchanan was not quite satisfied in his mind as to the correctness of the classification he had adopted, as his remarks following the list of fossils from the upper sandy beds clearly show. He says, "There is every probability that in addition to the above two beds [upper sandy beds and lower blue clays of Shakespeare Cliff] an older stratum exists, more inland, characterized by the presence of Cucullæa, and if the blue clay of the Patea River should prove to belong to this lower bed the proportion of extinct species in the Wanganui beds would be considerably diminished."—(Trans. N.Z. Inst., Vol. II., p. 164.)

b. *Kai-iwi Blue Clays.*—These clays are well exposed on the coast between Wanganui and Kai-iwi. They should perhaps include the blue clays at the base of Shakespeare Cliff, into which they pass almost imperceptibly, and without any marked change in their fauna. As previously stated, large blocks of pumice were

found near the base of these beds. They contain a great many finely-preserved fossils, of which a large collection was made, embracing about 86 per cent. of recent species.

c. *Pohangina, Kaimatera, and Okehu Pumice-beds.* — At the mouth of the Pohangina these beds consist of quartz-sands with fragments of waterworn pumice, and fine micaceous silts and clays, interbedded with beds of loose gravel, their total thickness being about 350ft. They flank on to the Ruahine Range for a distance of twenty-five or thirty miles above Ashurst; but their exact extension in this direction could not be determined, on account of the rugged and bush-clad character of the country along the foot of the range. The actual thickness of this series of beds is another point on which I was unable to form even an approximate estimate, chiefly on account of the great amount of disturbance which has taken place along the line of junction with the Palæozoic rocks. At many places in the high cliffs that bound the Pohangina River the beds are standing at right angles to their plane of deposition, and in the short distance of a few chains many faultings and dislocations may be seen.

The only fossil I could identify from these beds was *Venus stuchburyi*, which occurs only as casts.

At their base they are associated with beds of lignite, one of which at Coal Creek is said to be 6ft. thick.

In the upper part of the Pohangina the pumice-sands pass down into pale-blue sandy clays, which are interbedded with a heavy band of shell-limestone. These probably occupy the horizontal position of the Butler's Creek shell-beds, which occur at the base of the Okehu pumice-beds near Kai-iwi.

At Okehu and Kaimatera these beds consist of thin-bedded clays and sands and fine pumice-gravels. They are well exposed on the coast between Okehu and Butler's Creeks, whence they strike across the "Brunswick line" to Kaimatera Cliff, situated on the left bank of the Wanganui River. They contain an abundance of shells, most of which can be referred to recent species.

When Captain Hutton examined the Wanganui district in 1884 he considered the Kaimatera beds belonged to the Pleistocene period, chiefly, it appears, on account of the presence of pumice, which, he says, has never been found in his "Putiki series," which includes all the upper sandy shell-beds and blue clays between Wanganui and Patea (Trans. N.Z. Inst., Vol. XVIII., p. 339). However, I have already shown that pumice occurs in the upper sandy beds at Landguard Bluff and Putiki Cliff; in the Kai-iwi blue clays; in the Okehu pumice-sands, which are similar in character to and occupy the same relative position as the Kaimatera pumice-beds; and in the underlying Butler's Creek and Okehu shell-beds.

But, apart from the presence of the pumice, the inferior position of the Kaimatera beds is clearly shown by the stratigraphy

(Fig. 22); and this is the view held by Mr. C. W. Purnell, who divided the Wanganui Tertiaries into three groups: "The oldest fossiliferous stratum within a radius of four or five miles from the Town of Wanganui is the tuff in the cliffs on the east bank of the river [at Kaimatera]; the next oldest, the blue clay, at Shakespeare Cliff; and the youngest, the beds overlying the blue clay, and those of the Landguard Bluff."—(Trans. N.Z. Inst., Vol. VII., p. 453.)

d. *Butler's Creek and Okehu Sandy Shell-beds; and Brown Sands, Nukumaru Beach.*—The sandy shell-beds are seen to best advantage at the pits, between Okehu and Kai-iwi Stations, where they have been extensively quarried for ballasting the railways in this district. A large collection of shells was made here, of which about 83 per cent. are still living.

Mr. Drew, of Wanganui, discovered in these beds the fossil bones of a small seal and some bird-bones. The remains of the former, which were identified by Dr. Hector as probably *Arctocephalus cinereus*, consist of four dorsal vertebræ set in a hard calcareous sandstone matrix. They are much waterworn, and Mr. Drew is of the opinion that they were derived from an underlying bed which had been partially re-sorted; and this may probably have taken place, for, as already pointed out, the beds above the Nukumaru limestone were deposited during a period of gradual upheaval, and in consequence the littoral portion of the stratum underlying the Okehu beds would become dry land, and become subject to denudation during the deposition of the Okehu beds; and its contents would thus be redeposited.

Mr. Drew considered the bird-bones too large for the kiwi and too small for the moa; however, on examination they were identified as belonging to the latter. This, I believe, is the first discovery of fossil moa-bones in New Zealand.

The sandy shell-beds are well exposed at the mouth of Butler's Creek, where they are cemented into hard irregular bands which are separated by loose sands with shells in great abundance. North of Butler's Creek these beds are underlain by brown and yellow sands, in which I could find no fossils.

e. *Rotella Beds, Nukumaru Beach.*—These consist of loose sandy shell-beds, interbedded with irregular argillaceous limestone bands. They are richly fossiliferous, and a collection of their fossils was made, of which about 80 per cent. are recent. The most abundant shell is *Rotella zealandica*, which occurs in immense numbers in the loose sandy beds.

Older Pliocene—
a. Nukumaru, Kaiwaiki, and Pukiori limestones.

a. *Nukumaru, Kaiwaiki, and Pukiori Limestones.*—The above names apply to the same limestone, and indicate geographical distribution only. Wherever it occurs it consists of broken shells, sand, and pebbles, and where the sand occurs in thin layers it

becomes flaggy on weathered or exposed surfaces, and the shells contained in the sandy portion become free, and may thus be obtained well-preserved and with little difficulty.

This limestone occurs at water-level at Nukumaru Beach; at Kaiwaiki, on the Wanganui River; and a few hundred feet above the sea, near Pukiori, on the Marton–Murimotu track. From these places it extends inland, and is seen at Erehwon and on the flanks of the Ruahine Range. It is everywhere characterized by an abundance of large Balanus, but near its junction with the Palæozoic rocks it is composed almost exclusively of fragments of this crustacean, which however are rarely got in a perfect state.

Its thickness at Nukumaru beach is probably 250ft. in one unbroken bed, while at Kaiwaiki it occurs as a number of separate beds none of which exceeds 60ft. in thickness.

At Nukumaru and Kaiwaiki this limestone contains a large number of shells, of which from 75 to 80 per cent. belong to recent species. This high percentage of living forms would place it in the Newer Pliocene period, but, as its deposition shows that it is more closely associated with the underlying than with the overlying beds, I have placed it in the Older Pliocene period.

Upper Miocene—

a. Coralline series at Waitotara and Parakino.
b. Patea and Pipiriki blue clays and brown sands.
c. Argillaceous pebbly shell-beds at Manganui-a-te-ao; and Oarangi, Erehwon.
d. Blue clays with gritty shell-beds at Onaira; and Puketapu, Upper Wanganui.
e. Blue clays at White Cliffs; and Paparoa, Upper Wanganui.

a. *Coralline Series at Waitotara and Parakino.*—This series includes the soft brown micaceous sandstones underlying the Nukumaru limestone, the coralline beds and yellowish-blue sandy clays at Waitotara, and the Whenuakura blue clays. The shell-beds are well exposed in the railway-cuttings about a mile south of the bridge, and on the low hills on both sides of the river below the railway-line. The finest exposure is seen on the left bank of the river, opposite Wilkie's farm, where the shell-beds are together about 50ft. thick; the upper bed being composed of *Ostrea ingens*, large Pectens, and a number of fine corals and Bryozoa, the most characteristic and abundant of which is *Fascicularia intermedia*, Ten.-Woods, which is almost identical with *Fascicularia aurantium*, Milne-Edwards. This is an extinct genus which is considered characteristic of the older Pliocene crag of England and Europe. The lower bed consists of brown calcareous sands, with *Pecten radiatus*, *Waldheimia lenticularis*, corals, and a few *Ostrea ingens*. The upper bed generally assumes the character of a shell-limestone.

The yellowish-blue sandy clays below the shell-beds are seen on both sides of the river between Wilkie's and the village.

The Whenuakura blue clays are first seen on the coast, a few miles north of the Waitotara Heads, whence they extend to the north side of the Whenuakura River. They contain a gritty shell-bed with *Cardium spatiosum*, *Pecten athleta*, and several other forms found in the overlying beds; and about 60ft. below this a number of fossils occur in the blue clays, the most characteristic of which is *Ostrea ingens*.

This series of beds are again seen at Parakino, on the Wanganui River, whence they rise inland. They are found on Raetihi, near the source of the Mangawhero, at 3,200ft. above the sea; on the south flanks of the Kaimanawas at 3,700ft.; and on the Ruahine Range at 3,400ft., whence they appear to sweep into Hawke's Bay. Near their junction with the Palæozoic rocks they are associated with heavy beds of coarse rusty conglomerates.

b. *Patea and Pipiriki Blue Clays and Brown Sands.*—These beds lie conformably at the base of the coralline series, and represent a great thickness of strata, which is well exposed on the Patea coast; in the Wanganui River at Pipiriki; and to the east of this, in the great scarp-line on the south flanks of the Kaimanawa Range. At Patea and Pipiriki they are characterized by the presence of *Solenella australis*.

c. *Argillaceous Pebbly Shell-beds at Manganui-a-te-ao, and Oarangi, Erehwon.*—These beds were first described in the Upper Wanganui by Mr. J. C. Crawford, in 1862 (*Wellington Provincial Gazette*, 1862, p. 19), who examined them at the caves situated a few miles below the junction of the Manganui-a-te-ao; at the long reach above this junction; and at Utapu, below the mouth of the Tangarakau.

At Erehwon they are best seen in the high scarp on the south flanks of the Kaimanawa Range, where they consist of pale-blue sandy clays with argillaceous limestone-bands which contain fossils in great abundance. A large collection of these was made, of which about 55 per cent. are recent. These are the lowest beds seen in the Upper Rangitikei.

d. *Blue Clays with Gritty Shell-bed at Onaira, and Puketapu, Upper Wanganui.*—At Onaira these beds consist of blue clays and quartz and sandstone pebble-beds with hard argillaceous limestone bands; at Puketapu they are described by Mr. Crawford as blue clays mixed with quartz and sandstone gravels. The characteristic fossils of these beds at both places are *Dosinia grayi*, *Dentalium giganteum*, and *Pectunculus laticostatus*.

e. *Blue Clays at White Cliffs, and Paparoa, Upper Wanganui.*—The blue clays at White Cliffs are about 800ft. thick, and are underlain by thin-bedded clays with a great many concretionary nodules, which vary from a few inches to several feet in diameter. Fossils are not plentiful in the blue clays. The most common forms are *Solenella australis*, a Dentalium, and crustacean remains. At Paparoa, near the base of the blue clays (*Wellington*

Provincial Gazette, 1862, p. 19), Mr. Crawford made a collection of fossils which contains the same Dentalium and crustacean remains. In his list of fossils from this place he cites a large Cucullæa, which however is not represented in his collections in the Colonial Museum.

The thin-bedded strata underlying the blue clays at White Cliffs are apparently the lowest beds of the Tertiary system in Taranaki.

In the Hawke's Bay Province, where this series of Tertiary rocks is largely developed, several sections have been described that are probably equivalent to many of the sections of the Wanganui area. Mr. McKay has described the Shrimpton's–Kereru section as a complete sequence (Geological Reports, 1876–77, p. 76); and, with regard to the Petane–Mohaka section, both Mr. Cox (Geological Reports, 1874–76, p. 97) and Mr. McKay (Geological Reports, 1884, p. 185) consider the succession of the beds to be unbroken, and this view is fully supported by the sections already described in the Wanganui District, most notably those from Wanganui to Patea, Wanganui to Manganui-a-te-ao, and Marton to Erewhon.

The above sections may also throw some light on the age of the Scinde Island limestones and their probable position in the Petane–Mohaka section. These limestones are considered by all geologists, except Captain Hutton (Trans. N.Z. Inst., Vol. XVIII., p. 329), to be conformable to one another, and to belong to the same formation.

Last year Mr. McKay made a close examination of Scinde Island, and reports (Geological Reports, 1884, p. 185) that he is unable to find the unconformity pointed out by Captain Hutton.

On the 16th of June last I also examined Scinde Island, and could make out no unconformity, but was much interested to find that the sequence of the strata and their fossils very closely resembled the sequence and fossils of the older Pliocene period of the Wanganui and Rangitikei areas. This will be most readily seen by reference to the following tabulated view:—

Scinde Island Section.	Waitotara Section.
a. Upper limestone.	*a*. Nukumaru limestone.
b. Soft grey and brown sandstones.	*b*. Soft brown micaceous sandstones.
c. Lower limestone and calcareous sands.	*c*. Shell limestone and brown calcareous sands.

In both these sections the upper and lower limestones are separated by about 150ft. of soft sandstone.

The percentage of recent shells in the coralline limestone at Waitotara is about 65, and in the corresponding limestone at Scinde Island 62·5, according to Captain Hutton (Trans. N.Z.

Inst., Vol. XVIII., p. 330). However, I found in this limestone six species in addition to those cited by Captain Hutton, four of which are recent and two extinct, thus raising the percentage to 63·3 of recent species. These fossils were found at the site of the new harbour-works, on the north-east side of the island, in the new cuttings in the sea-face. They are—*Mytilus latus, Ostrea edulis, Pecten radiatus, Perna quadrata, Cardium spatiosum,* and *Waldheimia lenticularis.*

The 150ft. of sandstones between the upper and lower limestones appear to represent a considerable lapse of time. The Nukumaru limestone contains about 80 per cent. of recent species, and from the upper limestones at Scinde Island Captain Hutton enumerates forty-five species, of which thirty-eight, or 84 per cent., are recent; but if *Perna quadrata* and *Pecten triphooki,* which also occur in this limestone, are added, the proportion of recent species will be 80·5. The above species are both found in the Nukumaru limestone, but the latter is very rare.

The two limestones at Waitotara are undoubtedly represented in the Petane–Mohaka section by the upper and lower limestones at Pohui; and, if the Scinde Island limestones are also equivalent to the limestones at Waitotara, they must then be considered as equivalent to the Pohui limestones. When examining the Pohui section Mr. McKay noticed a similarity in the sequence of the beds to that at Scinde Island, and, in his paper "On the Age of the Napier Limestone," observes: "This represents the section in Scinde Island; that is, the succession and character of the rocks are the same. The fossils have yet to be exhaustively collected before this can by finally determined."—(Trans. N.Z. Inst., Vol. XVIII., p. 372.)

As Scinde Island is quite detached from the mainland, it is obviously impossible to accurately determine its position in the Tertiary series of Hawke's Bay by means of stratigraphy; consequently palæontology must be relied upon to effect this correlation.

There is no palæontological evidence whatever to support the correlation of the Scinde Island beds with the Petane beds. No doubt most of the recent forms found at Scinde Island occur at Petane, but none of the many extinct forms which specially characterize the former are known from the Petane beds, which have been most exhaustively collected from by Mr. Hamilton. On the other hand, all the species, both recent and extinct, from Scinde Island are found in the Te Aute beds everywhere in Hawke's Bay and Wanganui districts, which fully bears out the correlation I have made.

Cretaceo-tertiary—
a. Tufaceous greensands and crumbling marly clays, Mokau River.
b. Foraminiferous limestone.
c. Greensandstones and dark marly clays, with coal-seams.
d. Blue sandy clays, alternating with bands of marlstone.

The decomposing greensands and crumbling marly clays extend from the mouth of the Tongaporutu to the Mokau Heads, whence they can be traced in the banks of the river as far as Patokatoka, where the underlying foraminiferous limestone appears at water-level. In his report on the Lower Mokau, Dr. Hector mentions the occurrence of this limestone (Geological Reports, 1878–79, p. 20) at the mouth of the river, accessible only at low water. Its presence here shows that the overlying beds are contained in a low syncline between this place and Patokatoka, beyond which the limestone rises to N.N.E. at a low angle, exposing the underlying greensandstones and dark marly clays. These are the true coal-measures of the Mokau.

A short distance below the Panirau the rise of the beds exposes heavy-bedded blue sandy clays, which alternate with bands of hard marlstone, in which Dr. Hector informs me he found a fragment of a shell which he believed to belong to Inoceramus.

The heavy-bedded strata continue to rise to N.N.E., at a grade of about 1 in 20, almost to Mangatakiora Creek, where the dip changes to N.N.E., the beds at this place forming a low anticline, on the north side of which the beds are again repeated in their order of succession. The greensandstones and dark marly clays continue to Totoro, where they are followed by the limestone; and on the track to the Mokauiti these beds are seen resting successively on the Palæozoic rocks. The greensands on this side of the anticline also contain coal-seams.

At Patokatoka the limestone is probably not more than 60ft. thick; but at the Wairere Falls, where it rests hard on the Palæozoic rocks, it has developed a thickness of at least 150ft., and assumed the character of a littoral or shore limestone. It is now coarse and pebbly, and contains broken echinoderms and a large oyster, probably *Ostrea wullerstorfi*, in great abundance. At Patokatoka it is composed of finely-comminuted shells, and contains a large number of Foraminifera, the most abundant of which probably belong to the genus Amphistegina.

Carboniferous—
a. Siliceous sandstones and slaty shales, Ruahine and Kaimanawa Ranges.

These rocks have already been described as forming the Ruahine and Kaimanawa Ranges, on the eastern and northern boundaries of the area examined this year. A small isolated patch of a somewhat similar rock is seen at the Wairere Falls, in the Upper Mokau.

They consist of alterations of grey and green siliceous sandstones, with associated jasperoid and cherty bands and dark

crumbling slaty shales. In most places they appear to have been subjected to great disturbances, and are generally much crushed and broken. Traces of gold have been found in them at the Manawatu Gorge and the Kaimanawa Range, but, although a large amount of prospecting has been carried on at these and other places occupied by this formation, the results, so far, have not been very encouraging, the gold being mostly too finely disseminated to be payable.

Volcanic—
a. Volcanic tufas and agglomerates.
b. Extinct volcanoes, Ruapehu and Egmont.

a. *Volcanic Tufas and Agglomerates.*—A narrow strip of these has already been described as occupying a number of flat-topped hills in the valley of the Hautapu River, a few miles above its junction with the Rangitikei. This is the farthest they have been traced in this direction, and is the source of the volcanic boulders seen by Mr. Crawford in 1862, in the beds of these rivers. On account of the bush-clad character of the country I was unable to determine whether they were connected with some local volcanic disturbance, or were derived from Ruapehu. According to my field observations the rocks forming these agglomerates are the same as those at Ruapehu.

The plateau or "desert," as it is called, between Ruapehu and the Kaimanawa Range, consists of great accumulations of tufas and breccias, much of which no doubt has been ejected during former eruptions of Ruapehu; but the greater portion of the material, or at any rate that which now occupies the surface, appears to have been deposited by the numerous mountain-torrents that descend from the permanent snow-fields on its slopes. The general appearance of the "desert," as seen from a distance, is that of a great river-*fan*.

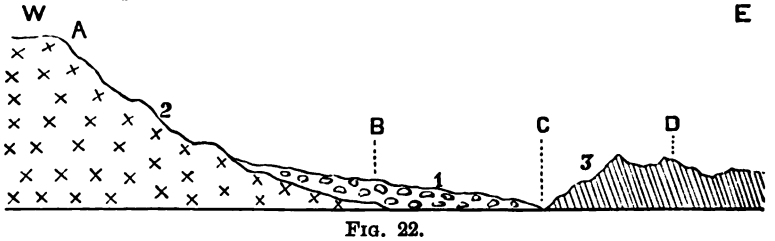


FIG. 22.

Section from Ruapehu to Kaimanawa Range; distance, 12 miles. A. Ruapehu. B. "Desert." C. Waikato River. D. Kaimanawa Range, 5,000ft. 1. Tufas, sands, and breccias. 2. Solid lava-flows. 3. Palæozoic rocks.

Fine sections of these tufas and breccias are seen in the sides of the deep streams on the south flanks of Ruapehu. They consist mostly of red and yellow clays, coarse grits, gravels, and breccias, with numerous large angular masses of rock. They often present a stratified appearance and affect the slope of the surface on which they lie.

In Taranaki, the tufas and agglomerates are very widely spread, but, except on the coast-line, rarely crop out at the surface, being deeply covered by the "drift." They crop out at many places along the coast, and reach their extreme north limit near the mouth of the Waiau River. They are extensively quarried at the Sugar-loaves and Sentry Hill, for road-metal purposes.

b. *Extinct Volcanoes, Ruapehu and Egmont.*—During the progress of this survey I ascended Ruapehu in order to observe its structure. The ascent was made from Karioi, on the 8th January last.

Near our camp at the top edge of the bush there occurs a great lava-flow of black compact dolerite, which contains numerous cavities lined with calc-spar. Proceeding up the mountain the next rocks met with are finely vesicular trachy-dolerites, of a deep red colour. These rocks cover a large area round the edge of the mountain, and are easily distinguishable at a distance by their colour. They form low ascending rocky ridges up to 5,000ft., above which the ascent is more abrupt and difficult. At this height I noticed several great bosses of solid agglomerate, which had probably solidified in the necks or vents of old craters, and are now partly exposed by the rapid denudation which is effected by the large streams that have scoured the slopes of this mountain into wide gulches and deep ravines on all sides.

Being early in the season, the slopes of the mountain above 5,000ft. were covered with snow and ice, and it was only at intervals, as when we encountered an *arête*, or a wall too steep to carry snow, that I was able to make observations as to the character of the rocks.

At 5,500ft. and 6,000ft. the rocks are phonolites or clinkstones of a grey colour, that display in a fine manner the general tendency of rocks of this group to split into slabs or slates. Many of the slabs here are several feet in extent, and vary from ¼in. to 2in. in thickness. On account of the snow I was unable to determine whether these rocks occurred as a lava-flow or a massive boss.

Above the phonolites appear dark-grey porphyritic trachytes, which continue up to 7,500ft. and form the high precipitous peak facing Karioi. On the north side of this peak there is a great boss or dome of dark smooth pitchstone, in which the lines of fluxion are well marked. Close to this, on the saddle leading from this peak to Paratetaitonga, the name by which the highest point of Ruapehu is known to the Natives, there is an extensive deposit of a yellowish-white siliceous rock, impregnated with sulphur, which has apparently been deposited by the action of hot springs that have existed here at one time.

The summit of Paratetaitonga, as well as all the peaks of almost equal height that surround the great crater of Ruapehu, were covered deep in snow, and I could not therefore see the rocks on the precise highest point; but about 20yds. north of this, and

at some 15ft. lower elevation, there was a small isolated outcrop of bare rock, which was a coarse vesicular trachyte, very much weathered.

At the time of my visit the centre, or rather the most depressed part of the crater, was occupied by a smooth sheet of clear ice, of a greenish-blue colour, which, in alpine regions, is generally considered characteristic of ice-fields of great depth and permanence.

Age of Ruapehu and Egmont.—The information obtained during the progress of this survey, relating to this question, appears to indicate—(1) That no contemporanceous outbursts took place in this area during the deposition of the older Pliocene strata of Wanganui and Taranaki; (2) that volcanic activity began in the early part of the newer Pliocene period, and has continued to the present time; or, in other words, that the formation of Ruapehu and Egmont has taken place since older Pliocene times.

Among the newer Pliocene strata of Wanganui, the first traces of volcanic activity are found in the Butler's Creek beds, in which large blocks of pumice are common, thus denoting that the first eruptions were terrestrial, and of a highly acidic character. From these beds upwards the evidences of volcanic activity are abundant. Further support is found at the Hautapu, where the volcanic tufas and agglomerates are resting on a highly-denuded surface of the younger members of the older Pliocene period (Fig. 4). This, I believe, is the only section in the Wanganui or Rangitikei areas that shows the relations of the volcanic rocks to these younger Tertiary beds, and is therefore of the greatest importance and value in dealing with this question.

As already pointed out, the newer Pliocene beds were deposited during a period of upheaval, which might probably have been induced by the commencement of volcanic energy in this area.

The Tertiary rocks near Ruapehu attain a height of over 3,000ft., and present a line of scarp to that mountain, evidently pointing to local depression in the immediate vicinity of the scene of volcanic energy: consequently no sections showing direct contact can be obtained there.

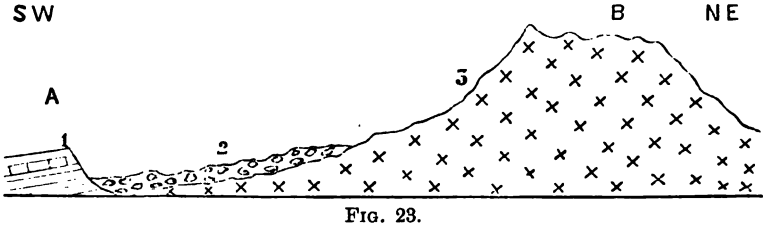


FIG. 23.

Section from the Mangawhero to Ruapehu; distance, 12 miles. A. Raetihi, 3,200ft. B. Ruapehu, 8,878ft. 1. Tertiary strata. 2. Volcanic tufas and breccias. 3. Solid lava-flows.

However, from the evidence previously stated, it appears probable that the formation of Mounts Egmont and Ruapehu commenced after the close of the older Pliocene period.

In 1860 Dr. Von Hochstetter included these mountains in his "newer volcanic formations" ("New Zealand," by Hochstetter, 1867, p. 67), and when describing the structure of this part of the North Island he illustrates the relations of the volcanic rocks to the Tertiaries by a section from Cook Strait to the Bay of Plenty, in which Ruapehu is shown to have burst through and spread itself over the Tertiary strata.

With regard to the age of the eruption of the younger volcanic formations, Dr. Von Hochstetter says that the volcanic outbursts began at the close of the Tertiary period, and have continued into the present times.

The greater part of the area forming the subject of this report is extremely rugged and covered with a dense vegetation, and, in the absence of roads or tracks, is at present almost inaccessible except by the river highways. On this account I was unable to traverse but a comparatively small portion in the time at my disposal, and have therefore no personal knowledge of the country in the Upper Wanganui from Pipiriki to Taumarunui, and from there to the Mokau; consequently, in preparing the accompanying map of the geology of this district, I have availed myself of all the information relating to these parts, more especially with regard to the extent of the coal-measures and the distribution of the volcanic agglomerates and tufas, which in previous maps, with perhaps the exception of Mr. Crawford's Geological Map of the Province of Wellington, 1862, occupy a much larger area than they are now known to cover.

First, with regard to the coal-outcrops which I have marked on the map.

In 1862 Mr. Crawford obtained specimens of coal from the Tangarakau and Ohura; but, on account of the obstruction of the Natives, he was unable to visit these places, and could therefore only approximately locate the seams. The Tangarakau seam was reported to be two days' journey up that river, and 8ft. thick; and the Ohura seam a short distance above its junction with the Wanganui, and 3ft. thick (*Wellington Provincial Gazette*, February, 1862, p. 12).

Mr. A. J. Rawson, in his report on the Stratford–Te Awamutu Railway route,* mentions the occurrence of coal-seams which crop out "in several places on the Tangarakau, and at the head of the Heao River, the seam where seen being 4ft. or 5ft. thick, with a slight dip to S."

Mr. T. M. Skeet, in his report on the same route, says, "The coalfield [of the Mokau–Wanganui district] is a very extensive

* Report of the Select Committee for North Island Trunk Railway, 1884, p. 101.

one, judging from the outcrops on the Lower Tangarakau, Middle Tangarakau, Heao, Okura (near Opatu Block), Mokauiti, Mokau, and indications also on the Tongaporutu, near the coast; in all, some thirty-two miles long by twenty wide."†

I did not see the coal mentioned by Mr. Skeet at the Mokauiti; but Mr. Paterson, of the Lower Mokau, who has an intimate acquaintance with the whole of the district, and to whom I am indebted for much information respecting the coal-outcrops and extent of the Mokau limestone, described its mode of occurrence and situation, so as to enable me to locate it in the map.

The other coal-outcrops marked on the map, with the exception of those in the Lower Mokau, which were seen by myself, were obtained from the maps of the General Survey Department, and Dr. Hector's large-scale map of the Lower Mokau, 1878.

The boundaries of the coal formation at Tahua and Ongaruhe were copied from Mr. Crawford's geological map, 1862; and at the Upper Mokau are the result partly of personal observation and partly of information derived from Mr. Skeet's report just referred to, and Dr. Hector's map.

The Volcanic Agglomerates and Tufas.—In his "New Zealand," 1867, Dr. Von Hochstetter refers to an extension of these rocks between Ruapehu and Cook Strait (Hochstetter's New Zealand, 1867, p. 378). Speaking of this, Mr. Crawford says: "In Hochstetter's section across the North Island he has put in the Whanganui Mountain as volcanic. We passed near its base, and I was unable to perceive any appearance of volcanic rocks about or near it. It appeared to me to be simply a scarp of marine Tertiaries, possibly, for some reason or another, less denuded than the surrounding land. As Hochstetter was never in the district himself, he must have been misinformed as to the geological character of this hill."—(Trans. N.Z. Inst., Vol. II., p. 352.)

In their evidence before the Committee for the North Island Trunk Railway, Mr. R. W. Holmes and Mr. Morgan Carkeek describe the country between Stratford and the Mokau as being occupied by papa rock (soft sandstones and blue clays). In reply to a question as to the possibility of getting ballast on this route, the latter says, "There is no ballast in that country for a railway from beginning to end of it. It is papa rock generally. After leaving the Patea River I did not see a stone till I got to the Mokau."†

In reply to the same question, Mr. Holmes says, "A little hard cemented gravel was seen in the Tangarakau River banks, and a small quantity of shingle was seen in the Mangaroa River."‡

* Report of the Select Committee for North Island Trunk Railway, 1884, p. 105.

† *Loc. cit.*, p. 31.

‡ *Loc. cit.*, p. 103.

ON THE GREY-MARLS AND WEKA PASS STONE IN KAIKOURA PENINSULA AND AT AMURI BLUFF.

REPORT BY ALEXANDER McKAY.

NARRATIVE.

Wellington, 19th August, 1886.

I HAVE the honour to report that, as instructed, I examined on the 15th January last the south-eastern part of Kaikoura Peninsula, and the following day made examinations at Amuri Bluff, verifying former observations as to the relation of the Grey-marls to the Amuri limestone. As I had to proceed by the steamer from Boat Harbour to Lyttelton, the time at my disposal was very short, and would not admit of such a careful search for fossils as I desired to make.

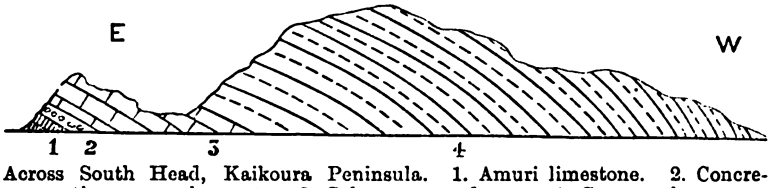
REPORT.

The greater part of Kaikoura Peninsula south-east of the Township of Kaikoura is formed of Amuri limestone and the overlying Grey-marls belonging to the same formation. Between these two rocks there is in places a development of calcareous sandstone, which, when present, is separated from the underlying Amuri limestone by a band of concretionary nodules similar to that seen in the same position at Amuri Bluff and in the Weka Pass section. This calcareous sandstone is not usually clearly and abruptly divided from the Grey-marls, its higher beds alternating with the lower beds of the Grey-marls at Kaikoura Peninsula, in the synclinal at the western end of the Amuri Bluff section. On the north-west side of the syncline formed by the Grey-marls in Kaikoura Peninsula beds of a more argillaceous type are in contact with the Amuri limestone. Where the junction is seen on the south-west side of the Peninsula, although the calcareous sandstone is well developed on the opposite side of the syncline, here it must be considered as represented by beds more approaching the ordinary characters of the Grey-marls than of the Weka Pass stone.

At the Port of Kaikoura I examined the junction between the Amuri limestone and the Grey-marls, and, although from the shattered condition of the lower rock there are places where the appearances might be considered as favouring the theory of an unconformity between the rocks, yet even here the general arrangement of the beds (excepting where they have manifestly been disturbed) is wholly in favour of conformity. This is the first locality showing the junction that most observers are likely to have studied, being within a few yards of the landing; yet it

has never been mentioned or sketched by those who contend that the Grey-marls are unconformable to the Amuri limestone. It may therefore be said that the evidence is scarcely in favour of unconformity.

Sections VII. and VIII. accompanying Dr. Von Haast's report are, however, quite conclusive as showing that unconformity is sufficiently marked in other parts of the Peninsula; and Professor Hutton is equally clear as to the unconformable relation of the Grey-marls to the Amuri limestone on the section from East Head south-west along the cliffs facing the sea (Geological Reports, 1873–74, p. 56), which certainly shows in such a manner that one would think it hardly possible to sketch sections covering over so little distance without these also giving unmistakable evidences of unconformity. When I last examined Kaikoura Peninsula I failed to detect these evidences except where the limestones are shattered close to the port, and where the strata were evidently disturbed by faults or by the action of the sea beating on and undermining the outer end of a bold promontory formed of calcareous rocks, such as part of this Peninsula is; and I saw nothing but conformity between the Grey-marls and the calcareous rocks under them. The following section shows the strata as disposed east-and-west across the southern point of the outer end of the Peninsula. The lower rocks are seen a little to the north-east of the point, and the section is thence carried west to the sea on the south-west side of the Peninsula:—

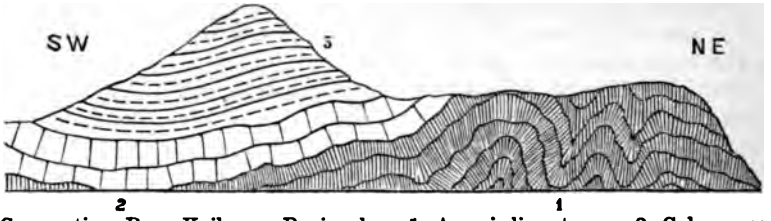


Across South Head, Kaikoura Peninsula. 1. Amuri limestone. 2. Concretionary conglomerate. 3. Calcareous sandstone. 4. Grey-marls.

The next section is taken a little farther to the north-east, and represents the same strata as seen on the south-west side of the little bay, after passing the caves:—

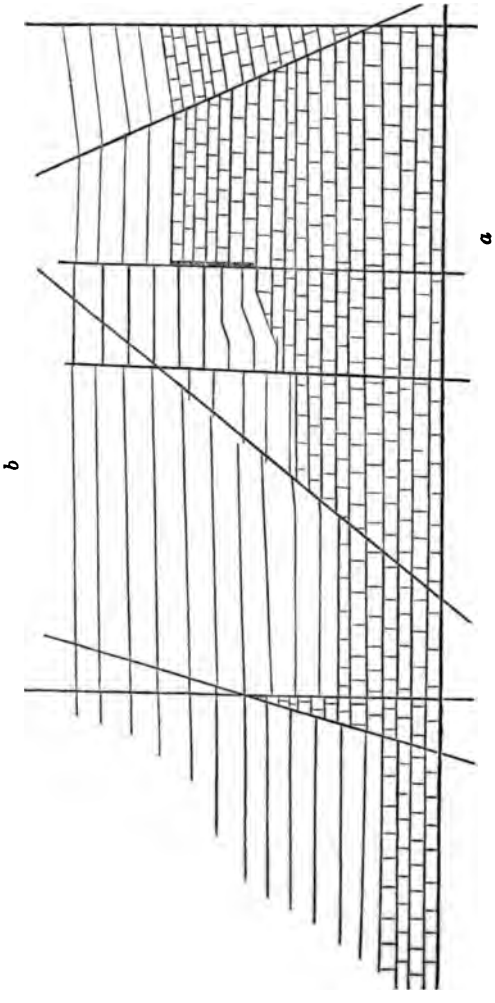
West end of Corrugation Bay, Kaikoura Peninsula. 1. Amuri limestone. 2. Calcareous concretionary conglomerate. 3. Calcareous sandstone. 4. Grey-marls.

Farther to the north-east the Amuri limestone is extremely corrugated, and otherwise disturbed, and here it might be expected unconformity, if present, would be sufficiently apparent. Below is a representation of the section as I sketched it on the spot:—



Corrugation Bay, Kaikoura Peninsula. 1. Amuri limestone. 2. Calcareous sandstone. 3. Grey-marls.

Professor Hutton gives the plan and a section of the junction between the Amuri limestone and the Grey-marls, as seen on the "South Beach" of the Peninsula. I may be mistaken as to the precise locality sketched by Professor Hutton, but I believe it to be that of which I here give a representation showing in what manner the junction is exposed on the beach where on the north-west side of the syncline the Grey-marls make contact with the Amuri limestone:—



Junction of Grey-marls and Amuri limestone, south-west side of Kaikoura Peninsula.
a. Amuri limestone. *b*. Grey-marls.

I found no fossils in the Amuri limestone, although sharks' teeth and shells have been reported.

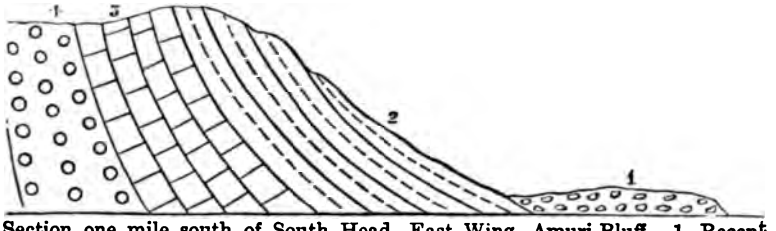
In the Grey-marls I found some fragments of bone, apparently cetacean, though possibly reptilian; also sharks' teeth and a small Pecten.

The calcareous sandstone at the base of the Grey-marls appeared to be unfossiliferous, and, although the concretionary conglomerate at the base of this contains fossils at Amuri Bluff, I sought here for such, or indeed any fossils, in vain.

I saw no thin beds of conglomerate such as Professor Hutton describes occurring in the Amuri limestone, unless the concretionary conglomerate just referred to be considered as such; but it cannot be regarded strictly as a conglomerate, and it certainly does not occur between beds of Amuri limestone.

At Amuri Bluff I examined the limestone exposure on the west side of the main anticline, and have no doubt as to the conformity of the Amuri limestone and the Grey-marls in this locality. The concretionary conglomerate is here well developed, and contains the oyster found in the underlying limestone. The concretionary conglomerate is overlain by from 15ft. to 20ft. of calcareous sandstone, probably representing the Weka Pass stone. The Grey-marls that overlie do not begin suddenly, but at first alternate with harder bands of the nature of the underlying sandstone.

On the east side of the anticline, as I did not visit the North Head of Amuri Bluff, I saw the junction of the Grey-marls at one place only—namely, half a mile south from the point where the track over Kai's Hill reaches the beach. At this point the Amuri limestone is exposed on both banks of a small creek, and in the cliff on the north side it is followed conformably by the Grey-marls, both rocks standing at a high angle.



Section one mile south of South Head, East Wing, Amuri Bluff. 1. Recent beach-gravels. 2. Grey-marls. 3. Amuri limestone. 4. Saurian beds.

In the section west from the south head of Amuri Bluff the junction of the Grey-marls with the Amuri limestone cannot be seen, and the published sections illustrating this but represent the inferences of the various observers, which are necessarily more or less hypothetical, and based on observations made elsewhere. The conformity of the beds is, to my mind, clear enough at Amuri Bluff itself, and again at one mile south of "South Head,"

and also under Mount Smith, on the west side of the anticline. Accordingly, in 1876 I represented the junction as given in the Geological Reports for 1874–76, p. 176, section A–A, although aware that Professor Hutton in 1873 had shown the Amuri limestone in the same line of section as being unconformably overlain by the Grey-marls.

It has been stated that the rapid thinning of the Amuri limestone between Amuri Bluff and Boat Harbour is a proof that it must have been denuded prior to the deposition of the Grey-marls, and that thus the latter must be unconformable to the Amuri limestone. The fact may be as stated, and yet be no proof that these two are unconformable, more especially if the views of Professor Hutton and Sir Julius von Haast respecting the conditions under which the Amuri limestone was deposited be correct. Professor Hutton maintains that the Amuri limestone was deposited not distant from land, (1) because beds of fine conglomerate are associated with it in Kaikoura Peninsula (?), and (2) because the Oxford chalk lies at the base of Mount Oxford, implying that the eastern slopes of that mountain formed the shore-line of the sea in which the Oxford chalk was deposited. Sir Julius von Haast states that the Amuri limestone in the Kaikoura Peninsula was deposited with the other beds of the series on a submarine rocky shallow, thus accounting for the flexuous disposition of the beds as there exposed. I do not wish to be understood as assenting to such views respecting the deposit of the Amuri limestone; but, if they be correct, it is not difficult to conceive that the Amuri limestone may be variable in thickness and yet conformably overlain by the next-succeeding beds.

ON THE JUNCTION OF THE AMURI LIMESTONE AND WEKA PASS STONE, WEKA PASS, NORTH CANTERBURY.

REPORT BY ALEXANDER MCKAY.

NARRATIVE.

Wellington, 26th August, 1886.

I HAVE the honour to report that on the 14th, 15th, and 16th of June last I examined the section seen in the Weka Pass, specially with reference to the relation of the Weka Pass stone to the underlying Amuri limestone as seen in the different exposures, natural and artificial, between the Weka Pass Hotel and the top of the Pass, the results of which work will be found in the following notes dealing with the above subject.

Report.

In the volume of Geological Reports for the year 1873–74, pages 43, 44, Professor Hutton says the sections in the Weka Pass and in the limestone gorge of the Waipara make this district the most important in New Zealand for studying the relations between the two formations (Waipara and Oamaru formations of the report). He further says, "In both the places mentioned the Weka Pass limestone is seen to rest on a water-worn surface of Amuri limestone," and that "at the base of the Weka Pass stone a thin bed of green calcareous sandstone containing pebbles of Amuri limestone is often seen." In the same place the Amuri limestone is described as much fissured, admitting of the less consolidated greensandstone finding its way some depth into the underlying much-fissured rock, and from a consideration of this circumstance he seems to have arrived at the conclusion that the Amuri limestone had been "consolidated, jointed, and waterworn before the Weka Pass stone was deposited upon it." He however admits that the dip of the two both at the Weka Pass and at the Waipara is the same, which must be acknowledged as a fact favouring their conformity to each other. However, it is but fair to state that, as evidence in the contrary direction, Professor Hutton mentions that in the surrounding district the Weka Pass stone overlaps the Amuri limestone considerably. This it may do, and yet it does not follow that the overlapping of the higher beds is decisive proof of their unconformable relation. Overlap need not, and does not of itself, prove unconformity. The same year, 1873, Dr. Hector, after a careful examination of the evidence obtainable at the Weka Pass, at Amuri Bluff, and Kaikoura Peninsula, was not satisfied that any stratigraphical break parted the Amuri limestone and the Weka Pass stone, which latter in the Weka Pass interposes between the Grey-marls and the Amuri limestone.

During the latter part of 1874 I examined the Weka Pass section, and sections of the same rocks in Weka Creek and in the Middle and Upper Waipara, and in the localities mentioned ascertained the conformity of the Amuri limestone to the Weka Pass stone, and of the Grey-marls to the latter. As has been stated by Professor Hutton, I then noted apparent conformity between the Grey-marls and the Mount Brown beds; and I must still say that to me they appear to be stratigraphically conformable; but it does not thus follow that they are so, and there are good reasons for thinking otherwise. Professor Hutton seems to think that this admission on my part is proof that I regard them as belonging to the same formation. Whatever their relation may prove to be, I at that time only stated what I believed was to be gathered from a study of the stratigraphy of the district: but I need not discuss this matter now, as it scarcely comes within the scope of this report.

In his "Geology of Canterbury and Westland" Sir Julius von

Haast discussed the relation of the Amuri limestone and the Weka Pass stone, and reaffirmed his previous conclusion that the beds were conformable, and belonged to the same formation.

In a paper "On the Reptilian Beds of New Zealand" (Trans. New Zealand Inst., Vol. IX., p. 581) I notice the presence at Amuri Bluff of a representative of the calcareous greensandstone of the Weka Pass section, and state that this is parted from the Amuri limestone by a rubbly bed of calcareous greensand occurring as nodules in a greensand matrix. This I believe to be the equivalent of the every-way similar bed occurring at the Weka Pass between the Amuri limestone and the Weka Pass stone, and which at the Weka Pass it is asserted contains rolled fragments of Amuri limestone. In 1874, after having seen the junction at the Weka Pass, I had doubts as to the real nature of these so-called pebbles or fragments of Amuri limestone, and, elsewhere in the same district noticing somewhat similar concretions in beds that underlay the Amuri limestone, I held that, as these latter could not be derived from a subsequently-formed rock, so neither could those in the higher beds be derived from the Amuri limestone. I held that in both cases we had to do with concretions, and not with the proceeds of denudation.

In a paper on "The Geological Position of the Weka Pass Stone" (Quarterly Journal of Geological Society, 1885) Professor Hutton says (p. 268): "In 1873 I distinguished the Amuri limestone from the Weka Pass stone, showing that the latter passed into a thin layer of calcareous greensandstone, which rested on a waterworn surface of Amuri limestone. I also pointed out that the apparent unconformities were deceptive, and due to a fault; and that in reality the Weka Pass stone, the Grey-marl, and the Mount Brown beds were all conformable." And on the following page he says: "In my report of 1873, just mentioned, I said that here [in the Weka Pass], as at the Waipara, the Weka Pass stone rested on a waterworn surface of Amuri limestone. As the correctness of this statement has been denied,* I again visited the locality last December, but see no reason to alter my former opinion." The great masses of limestone which are seen on the west side of the road in the centre of the pass, and on both sides near the northern end, belong to the Weka Pass stone. The Amuri limestone hardly shows in the pass, but is exposed in a cutting made by the Weka Creek a little to the north of the railway viaduct, where both railway and road cross the stream, about a mile and a half from the north end of the pass, or two miles and a half from the Waikari Railway-station. Here the stream has cut a small gorge on the east side of the railway and parallel to it, in which the junction of the two rocks is clearly exposed. This is, I believe, the only section in the neighbourhood in which the actual junction of the two rocks can be studied.

* See above; also Geological Reports, 1873-74: Progress Report, p. x.

Both rocks have here the same dip, but they are easily distinguished. The Amuri limestone is a white, rather argillaceous, much-jointed limestone, in thin parallel beds, and the exposed surface has consequently a shattered appearance. The Weka Pass stone is a pale-yellow or whitish arenaceous limestone, with scattered green grains, which get more abundant near the base, but are never sufficiently numerous to give it a green colour. The exposed surface is honeycombed, thus strongly contrasting with that of the Amuri limestone. A close inspection shows that the upper surface of the Amuri limestone is much broken and fissured, the Weka Pass stone penetrating into the fissures for a distance of one to two feet, with an abrupt division between the two rocks. Also rounded pebbles of Amuri limestone are found in the Weka Pass stone within six inches of the junction, but not higher. These pebbles are not concretions, as has been supposed, for they are exactly similar in composition and structure to the Amuri limestone, on which they lie, and are quite different in appearance from the concretions found in the greensandstones underlying the Amuri limestone.* Evidently, we have a waterworn surface, and therefore, as the nature of the upper rock excludes the idea of chemical erosion, we have an unconformity." This is the stratigraphical evidence on which Professor Hutton relies for proof of unconformity of these two rocks in the Weka Pass. As stated, it does not agree with observations of Dr. Hector or myself, and hence arose the necessity of making yet another examination of the Weka Pass section.

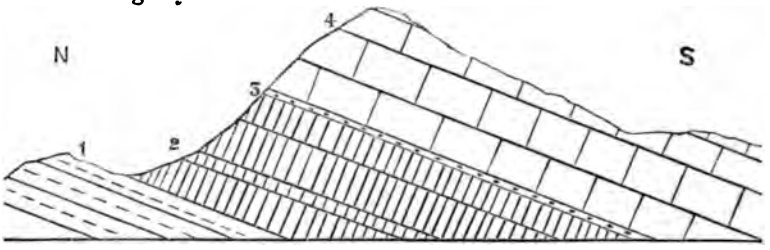
I examined carefully the different exposures of the junction between the Amuri limestone and the Weka Pass stone, and was more fortunate than Professor Hutton as regards the number of localities at which this can be seen. From the above quotation it would appear that he has seen the junction at one place only, viz., in the Little Gorge cut by the Pass Creek, close to where this is crossed by the road and railway-viaduct; but the section he gives (Quarterly Journal of Geological Society, 1885, p. 269, f. 2), north-and-south along the east side of the Pass, shows this, as well as the reappearance of the Weka Pass stone on the south side of the fault marked in the section. Amuri limestone, which there appears under the Weka Pass stone, is also shown in Section X. accompanying the report of 1873, and his description of the junction applies better to this southern exposure than to that seen in the Little Gorge.

On the left bank of the creek the junction may be seen in the gorge of the creek a short distance below the viaduct, and very

* Professor Hutton seems to have concluded as to the nature of these pebbles from appearances only, and by the same rule I decided differently in 1874: further on the result of their analysis will be given. No one ever held that they at all resemble the saurian boulders, or the fucoidal concretions of the greensands overlying the saurian beds.

clearly on the precipitous scarp of limestone which from this place runs west to the east side of the upper part of Weka Creek, opposite the northern end of the Doctor's Range. Following the road south through the Pass, the junction is clearly exposed a quarter of a mile before reaching the Pigeon Rock, at and near where a small creek coming down from the range on the east side crosses the road, and a breastwork to secure the road has been built. The junction is again seen in Pigeon Rock itself, and farther down the creek, where this runs along the foot of the limestone hills on the west side of the Pass, and yet again on the same side of the creek before the road crosses to the right bank before reaching the Weka Pass Hotel. There are thus in the Weka Pass at least six exposures where the junction between these two rocks—the Amuri limestone and the Weka Pass stone—can be studied, and within a mile to the westward it may be seen at as many more. I do not, however, propose to describe the junction at all these places, but will confine myself to those seen in the Weka Pass itself.

Commencing with that seen in the Little Gorge on the east side of the railway-line, the following woodcut is from a sketch made during my last visit :—



Section through gorge near railway viaduct, upper part of Weka Pass. 1. Greensands under Amuri limestone. 2. Amuri limestone, in bands of various thickness. 3. Junction-line between Amuri limestone and Weka Pass stone, with nodules of phosphate of lime. 4. Calcareous greensandstone (Weka Pass stone).

The greensands under the Amuri limestone are not clearly exposed in the line of section, and their junction with the limestone is not seen. The Amuri limestone is not here a thin flaggy limestone, but shows as heavy bands 3ft. to 5ft. or more in thickness, the bedding of which, as shown in the section, is parallel to the under-surface of the Weka Pass stone. The Amuri limestone is much jointed at right angles to the bedding of the thick bands of stone just described, and it thus assumes a columnar structure, which, with the less apparent and thinner bedding, gives it a shattered appearance.

The upper bed in contact with the under-surface of the Weka Pass stone is not more shattered than the underlying thick bands of strata, which are clearly indicated by thin partings of a less indurated character. Each particular thick band is formed by thin laminæ of limestone, and in all the beds there the continuity of

these is interrupted by vertical joints; but the uppermost of the thick bands, as a result of this jointage, is not more shattered than those that underlie; and nothing in this section can fairly lead up to the belief that the shattered character of the Amuri limestone is the result of causes operating on a rocky surface subjected to denudation. This shattered condition of the Amuri limestone is its usual characteristic where the beds form a hard limestone, and is the result of a number of causes, some of which have to do with its character as a chemical compound.

The upper surface of the Amuri limestone is distinctly marked in this section, and is followed by the soft greensand bed at the base of which the so-called pebbles of Amuri limestone occur. It is scarcely correct to speak of this greensand bed as a greensandstone, and still less is it right to confound it with the more calcareous rock overlying. Its degree of induration is not greater than that of many beds correctly spoken of as greensands but little consolidated, or as very soft greensandstone. In the exposure here described it scarcely, if at all, finds its way into the joints of the underlying limestone, and, as the Weka Pass stone, is quite a distinct rock, and overlies the concretionary greensand bed, so that, unless this be absent, the Weka Pass calcareous greensand —a moderately hard rock—could not rest on the Amuri limestone. This greensand band has been distinguished by every observer, and specially described as a distinct rock. When, therefore, it is said that the Weka Pass stone penetrates to some depth the fissures in the Amuri limestone, the concretionary greensand, and not the Weka Pass stone, is to be understood as doing so.

The section in the Little Gorge north of the railway-crossing illustrates badly this penetration of the greensands into the joints of the underlying limestone. Another exposure farther down the Pass shows it to better advantage, as there the greensands do penetrate the limestone in some places to the depth mentioned by Professor Hutton, and also contain plentifully the fragments, pebbles, or concretions that are or are not derived from the Amuri limestone. It was from this southern exposure of the greensand bed that I collected specimens of these concretionary nodules, selecting both the largest and the smallest showing in the face whence they were taken. I also collected samples of the Amuri limestone; and both rocks have been analysed in the Colonial Laboratory, with the following results:—

Amuri Limestone.

A sample taken *in situ* from the right bank of Pass Creek, near the railway viaduct, yielded 57·26 per cent. of lime carbonate; the residue, 42·74 per cent., being "almost pure sand (fine-grained)."

Calcareous Nodule from Greensand Band at Base of Weka Pass Stone.

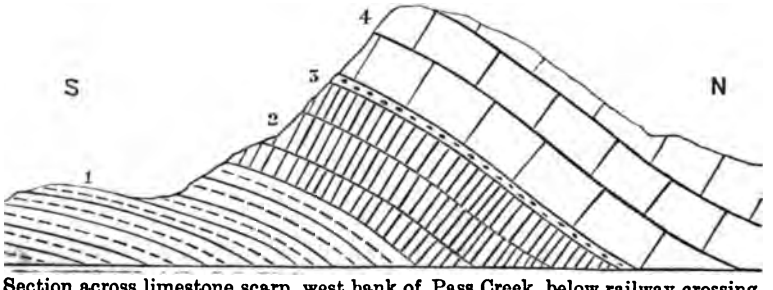
Lime	42·18 per cent.
Phosphoric acid	17·45 "
Matter insoluble in acid	5·79 "
Water	4·86 "
Carbonic acid	15·36 "
Alkalies and loss	14·36 "
	100·00 "

The phosphoric acid represents the presence of about 37 per cent. of anhydrous calcic phosphate.

The samples analysed differ so much in chemical composition that it is needless to say they cannot be the same rock, and even in the matter of the insoluble residue this difference is very apparent.

There is therefore in the Little Gorge no evidence of unconformity, excepting the abrupt termination of the Amuri limestone in the vertical section, and its being followed by a bed of greensand. It is no uncommon thing to find the Amuri limestone alternating with beds of greensand, as may be seen in the Clarence Valley, where the grandest display of this member of the Cretaceo-tertiary series takes place; and the same thing is finely illustrated at the mouth of the Pahau River, on the east coast of Wellington, and at other places between Cape Palliser and Flat Point. Such greensand bands do not occur in the Weka Pass stone at the Weka Pass, and consequently the greensand band at its base may with propriety be considered as distinct.

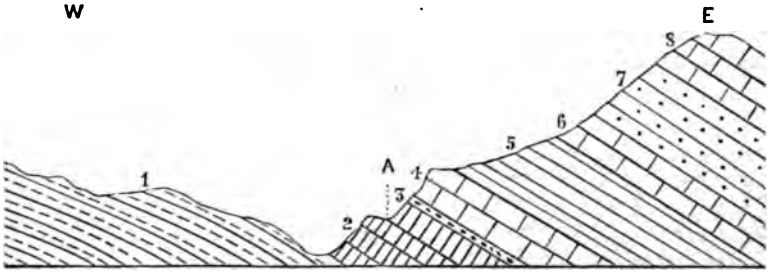
Below the crossing of the road and railway over the creek near the north end of the Pass a second gorge is formed, at the lower end of which the Amuri limestone is again exposed on both banks of the creek. On the west side a high precipitous face of rock terminates the scarp of limestone extending from the upper part of Weka Creek to Pass Creek at this place. The dip here has changed to N.N.E., and consequently a syncline is formed between here and the Little Gorge, east of the railway-line. In other respects the two sections agree remarkably.



Section across limestone scarp, west bank of Pass Creek, below railway-crossing. 1. Greensandstone. 2. Amuri limestone. 3. Greensand band with phosphatic nodules. 4. Weka Pass stone.

Farther south, on the west side of the Pass, both the Amuri limestone and the Weka Pass stone are absent till the northern end of the range at the back of the Weka Pass Hotel is reached; but from opposite the precipitous cliff, sketched in the section above, the Amuri limestone is traceable a short distance along the left bank of the creek, and may be found to continue as far as the next outcrop, a quarter of a mile north of Pigeon Rock; but at present it cannot be traced all the way, and there may be an interruption of the limestone.

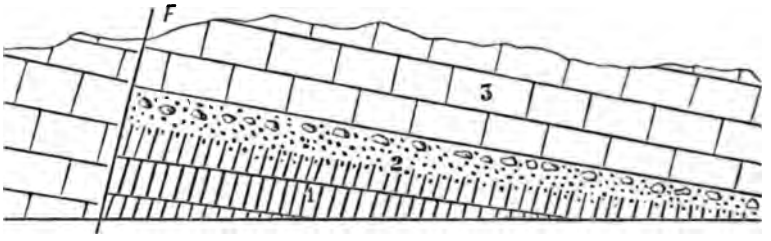
At Parapet Rock, where the limestone shows in the road-cutting, the following section east-and-west across the Pass is seen:—



Section at Parapet Rock. 1. Greensands under Amuri limestone. 2. Amuri limestone. 3. Greensand band with phosphatic concretions. 4. Weka Pass stone. 5. Grey marls. 6–8. Tertiary. A. Parapet Rock.

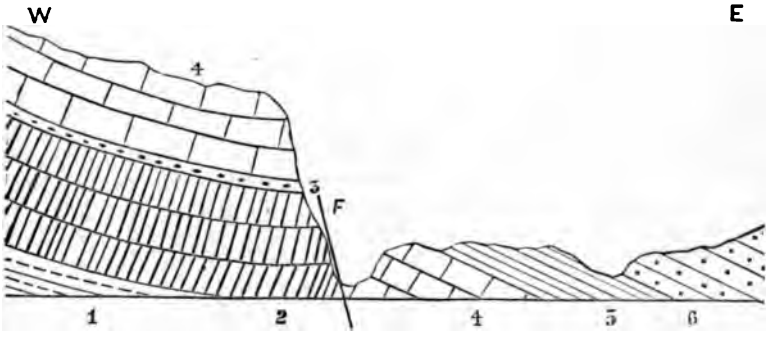
The character and the sequence of the rocks represented in this are the same as in the sections already sketched, the only difference being the more shattered condition of the Amuri limestone at its upper surface, thus admitting the overlying greensands into the crevices and fissures in the lower rock. It is maintained that this is a proof of unconformity; but, considering the nature of the upper rock, and that the Amuri limestone as exposed forms the crown of an anticline in the near presence of a fault (see Journal of Geological Society, August, 1885, p. 269), it is not surprising that the upper beds of the limestone should be fissured to an unusual degree, or that the soft greensands should find their way some depth into the uppermost limestone bed.

Since the section does not otherwise show evidences of unconformity, the strike of both beds being the same, and the dip the same in direction and degree, before stratigraphical unconformity can be proved it must be shown that what now appears as proving this was not the result of movements of the strata subsequent to the deposition of the Weka Pass stone. The following sketch shows the nature of the junction north and south of A in the section above:—



Sketch showing junction of Amuri limestone and greensand bed at Parapet Rock. 1. Amuri limestone. 2. Greensand bed with phosphatic concretions. 3. Weka Pass stone. F. Fault.

The same sequence may be seen at the Pigeon Rocks farther down the Pass, and again on the west side of the Pass, a few chains before the road crosses to the west bank of the creek, where the section represented below may be seen :—



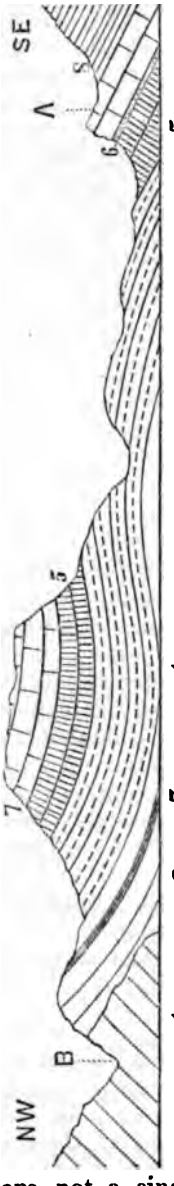
Section across Pass Creek, 5 chains beyond crossing north of Weka Pass Hotel. 1. Greensands (not seen, save farther north). 2. Amuri limestone. 3. Greensand bed between Amuri limestone and Weka Pass stone. 4. Weka Pass stone. 5. Grey-marls. 6. Sands. F. Fault.

A similar section is exposed a little farther north on the same side of the creek, and again at Pigeon Rock, though at the latter place the phosphatic bed is not developed as clearly as in the sections given.

The section from Pigeon Rock north-west to the northern source of Weka Creek shows the complete sequence of the Cretaceo-tertiary rocks of the district, and does not in the least favour the idea of an unconformity between the Amuri limestone and the Weka Pass stone.

The section along the west side of the Pass nearly at right angles to the last does not show any feature that has not been illustrated in one or other of those already given; it is therefore needless to reproduce it here.

This being the stratigraphical evidence the essentials of which are admitted by Professor Hutton,—who alone contends for stratigraphical unconformity, and that only on the grounds, first, that the fissured condition of the Amuri limestone has admitted of the greensands reaching some distance into the fissures formed; secondly, that the Amuri limestone is not everywhere present under the Weka Pass stone,—the phosphatic concretions cannot longer be considered Amuri limestone, though their presence in the greensand bed is held to be a third evidence favouring unconformity. The first and third may be considered disposed of. With regard to the second there is no direct evidence obtainable in the Weka Pass itself, but the analysis of the Amuri limestone, the results of which have already been given, shows that within a comparatively short distance its character might so alter that it would be incorrect to speak of it as a limestone, if indeed the beds in the Weka Pass can be so called. Again, it is of no great thickness—less than 50ft. according to my estimate. And, should the percentage of sand be much increased, the equivalent beds three or four miles distant might very well be mistaken for other than they are, or be absent.



Section from Pigeon Rock, Weka Pass, N.W. to north source of Weka Creek. 1. Old Secondary (Triassic). 2. Sands, &c., occupying the horizon of the coal at the Waipara and Malvern Hills. 3. Black oyster-bed and ferruginous sandstone. 4. Greensands (=saurian beds). 5. Amuri limestone. 6. Greensand band with phosphatic nodules. 7. Weka Pass stone. 8. Grey-marls. A. Pigeon Rock. B. North branch of Weka Creek.

As regards the palæontological evidence, this it has been said is overwhelmingly in favour of unconformity, and Professor Hutton is of opinion that "hardly any species of Mollusca, perhaps not a single one," will be found on both sides of a line dividing the Weka Pass stone and the Amuri limestone, or, in other words, above and below the supposed unconformity which he would attempt to show separates these rocks. He mentions four species of Mollusca as occurring in the Weka Pass stone at the Weka Pass, namely,

Voluta elongata, Hutton; *Scalaria rotunda*, Hutton; *Struthiolaria senex*, Hutton; and *Pecten hochstetteri*, Zittel,—none of which it is said are known from the "Waipara system" as this is understood by Professor Hutton. *Pecten hochstetteri* and *Struthiolaria senex* may be Tertiary fossils, but it is questionable if the varieties of these found in the Weka Pass stone are the same as the forms found in the Pareora beds of South Canterbury; and, as most of the calcareous rocks in which they are found are claimed to belong to the horizon of the Weka Pass stone (even according to Professor Hutton, the middle division of the Curiosity Shop beds), whether in the North or the South Island, it does not appear to me that any definite purpose is served by asserting the fossils of one locality to be the same as found in the equivalent beds of another locality.

It is true that, up to the present, the species mentioned have not been found in the Amuri limestone at the Weka Pass or in its immediate neighbourhood, and, as coming from the Amuri limestone itself, there is not a single species mentioned in Professor Hutton's paper "On the Geological Position of the Weka Pass Stone;" so that, as concerns the Weka Pass district, when his paper was written there may be said to have been no palæontological data on which to found any conclusion whatsoever. The only rational conclusion to be arrived at was according to the fact that there were a few fossil molluscs found in the Weka Pass stone and none in the Amuri limestone, hence not a single species transgressed the boundary-line separating these two rocks. And this applies whether the vicinity of the Weka Pass alone or the other localities mentioned in Professor Hutton's paper be considered, since only *Pecten zittelli* is mentioned as a fossil of the Amuri limestone. Even this species is discredited as having been found in the Amuri limestone itself, and it is assumed that it in reality comes from the Grey-marls.

This, as I have already put it, is the case from Professor Hutton's point of view; but the facts are somewhat different from what are stated as such by him, and, although a complete list of the fossils which, occurring in the Amuri limestone and the underlying beds, are common to the overlying beds, cannot at present be given, such a number of species may be cited as must lead to a very different conclusion from that which takes for granted that no fossils are common to the beds above and below the upper surface of the Amuri limestone.

In compiling such a list I shall deal (with one exception, the Oxford chalk) only with beds that are acknowledged by all to be of the age of the Amuri limestone or older.

Sir Julius von Haast obtained from the beds overlying the saurian greensands in Bobby's Creek *Waldheimia lenticularis*, and in the overlying beds before reaching the Amuri limestone *Scalaria browni* (?) (Geological Reports, 1871–72, pp. 11, 12);

at Amuri Bluff, in the lower beds of the section, *Dosinia greyi*. He mentions Vermetus, Teredo, and Terebratula as occurring in the Amuri limestone, but as he gives no specific names to these, and as they have not since been named, these are of no value for my present purpose. From the uppermost beds of the Amuri limestone in the Conway section he collected teeth of Lamna. He also mentions the occurrence of large fucoids in the Amuri limestone, which are so peculiar that there is no mistaking their identity; and he mentions the occurrence of this "peculiar fucoid" in the Conway section in beds overlying the Amuri limestone. It is common in the Grey-marls at Amuri Bluff, and is abundant in the Cobden limestone on the west coast of the South Island (Geological Reports, 1871–72: Report on Amuri District).

The same author, in "The Geology of Canterbury and Westland," at page 295 mentions *Cucullæa alta*, Sowb., and *Cucullæa ponderosa*, Hutton, as being fossils of the Waipara formation, and as occurring in beds that underlie the Amuri limestone, or the chalk-marls of the Trelissick Basin, which, it is not disputed, are the equivalents of the Amuri limestone. He says, "The lowest chalk-marls have yielded hitherto no fossils except a number of Foraminifera, of which I have recognised several species as being identical with those described by Karr and Stache in the palæontological portion of the great 'Novara' work."

In the volume of Geological Reports for 1873, pp. 37–40, Professor Hutton mentions, as occurring below the Amuri limestone, *Dentalium majus*, Sowb., a fossil of the Tertiary beds of Chili; *Cucullæa alta*, Sowb., described from the Tertiary beds of Patagonia; and *Cucullæa ponderosa*, Hutton,—all three of which are cited by him as found in the Miocene beds of New Zealand. He mentions also a Dosinia, without doubt the same as that mentioned by Dr. Von Haast as *Dosinia greyi*. He also mentions as occurring in the Amuri limestone "three species of Pentacrinites, two of which cannot be distinguished from *P. rotatus* and *P. stellatus* of the Oamaru formation."

When I examined the neighbourhood of Amuri Bluff in 1875 large collections were made from the saurian and underlying beds. These collections have yet to be examined with a view to the description of the new species they may contain; but, in addition to the species mentioned by Dr. Von Haast and Professor Hutton, I found a Crepidula (Crypta), which certainly looks very like *C. profunda*, Hutton, and was identified as such by Professor Hutton on my showing him the specimen in the Colonial Museum, as he passed through Wellington during the summer of 1884–85. Higher in the section the saurian concretions yielded a few fossils, among which were specimens of *Lucina selwynensis*, Hector, MS., which during the summer of 1884–85 I collected from the Grey-marls of Waipapa Boat-harbour four miles south of the

mouth of the Clarence River. From the Amuri limestone I collected an oyster identical with that found in the calcareous beds at Point Elizabeth, which, if not *Ostrea subdentata* of Hutton, approaches it in character. There is no doubt of the identity of the Amuri Bluff and the West Coast specimens; but it is not necessary that the comparison should be made, since at Amuri Bluff the fossil occurs both in the Amuri limestone and in the overlying concretionary greensand bed in which bones of *Palæeudyptes antarctica*, Huxley, and teeth of Lamna are also found. I collected this same oyster from the Amuri limestone in the Weka Pass during my last examination of the district. *Pecten williamsoni*, Zittel, is not rare in the Amuri limestone on the west side of the anticline at Amuri Bluff. *Rhynchonella squamosa*, Hutton, is also occasionally to be found. Teeth of Carcarodon, belonging to the same species, are found in both the Weka Pass stone and the Amuri limestone.

During the early part of 1885 I collected *Aturia ziczac*, associated with ammonites, belemnites, and Inoceramus, at Coverham, in the Middle Clarence Valley; and during the past season, from the large concretions immediately overlying the shell-beds of the Selwyn River, Malvern Hills, I obtained a number of the large vertebræ of an elliptic form that were first collected from the Grey-marls at Amuri Bluff. These vertebræ have not been determined specifically, but they are so peculiar that there is not the least difficulty in coming to the conclusion that the specimens from the Grey-marls at Amuri Bluff and those found in the saurian boulders of the Selwyn River must be referred to the same species.

I might refer to a number of species found in the limonitic sandstone overlying the Shag Point coal, and forming the eastern slope of Puke Iwitai, in the Moeraki district of Otago; but, though these beds are acknowledged by Professor Hutton to belong to the Waipara formation, I need not at present take these into consideration. There are a number of beautifully-preserved Foraminifera found in the Amuri limestone at Amuri Bluff, of which several are identical with species described in the palæontological portion of the "Novara" publications; but, as these may be held to have but little value for the purpose for which I should have to cite them, I refrain from doing so.

Teeth of Lamna ..	.. Haast.	Cucullæa alta, *Sowb.*	.. Hutton.
Teeth of Carcarodon	.. McKay.	Cucullæa ponderosa, *Hutton*	Hutton.
Vertebræ of peculiar form	.. McKay.	Waldheimia lenticularis	.. Haast.
Aturia ziczac, *Sowb.*	.. McKay.	Rhynchonella squamosa, *Hutton*	McKay.
Scalaria browni (?), *Zittel*	.. Haast.	Pentacrinus stellatus, *Hutton*	Hutton.
Crypta profunda, *Hutton*	.. McKay.	Pentacrinus rotatus, *Hutton*	Hutton.
Dentalium majus, *Sowb.*	.. Hutton.	Foraminifera, several species	Haast. McKay.
Ostrea ..	.. Hutton.	Fucoid of Amuri and Cobden limestones	McKay.
Pecten zittelli, *Hutton*	.. McKay.		
Pecten williamsoni, *Zittel*	.. McKay.		
Dosinia greyi, *Zittel*	.. Haast.		
Lucina selwynensis, *Hector*, MS.	Hector. McKay.		

All these fossils are common to beds above the Amuri limestone; although scarcely any of them are found in the Weka Pass stone of the Weka Pass district, and although not the species cited by Professor Hutton as the fossils of the Weka Pass stone, they have all been collected in the district of the east coast of the South Island lying between the Waimakariri River and Kaikoura Peninsula, and from beds lower than the Weka Pass stone, and all are found in beds considered by Professor Hutton as of the same age as, or younger than, the calcareous rocks of his Oamaru formation.

It may thus appear that a mistake has been made in asserting the opinion that, "if the line between the Waipara and Oamaru systems [of Hutton] be taken immediately above the Amuri limestone, hardly any species of Mollusca—perhaps not a single one—will be found on both sides of it,"* and it will be equally evident that there is no proof of a palæontological unconformity at this horizon. As little can it be said that there is any evidence of a stratigraphical unconformity between the Amuri limestone and the next overlying rock in the Weka Pass, so that any unconformity which may exist must be sought for higher or lower in the sequence of strata represented by the Weka Pass and Waipara sections.

If an unconformity should be proved between the Amuri limestone and the saurian beds, this could scarcely affect the integrity of the Cretaceo-tertiary formation, since there is no doubt that ammonites lived during the period of its deposition, and are now found fossil in the Amuri limestone. And, if the unconformity be placed higher than the position of the Weka Pass stone, then it matters little at what horizon it is placed; since, as pointed out by Professor Hutton, a fauna having strong Tertiary affinities will be included with the lower beds, and these would thus be properly referred to the Cretaceo-tertiary formation.

ON THE IDENTITY AND GEOLOGICAL POSITION OF THE GREENSANDS OF THE WAIHAO FORKS, WAIHAO VALLEY, SOUTH CANTERBURY.

Report by Alexander McKay.

Wellington, 2nd September, 1886.

On the east coast of the South Island, between Kaikoura Peninsula and the Rakaia River, the sequence of strata having the coal-beds of the Malvern Hills, Waipara, &c., at its base, and the Amuri limestone towards the upper part, is by most New Zealand geologists considered to be of young Secondary or Cretaceo-tertiary age. Sir Julius von Haast for many years maintained

* Hutton: Quarterly Journal of Geological Society of London, 1885, p. 277.

the Tertiary age of the beds in the Malvern Hills and at the Waipara, and prior to the 1879 held that, with the exception of some lignite beds of manifestly younger date, all the coal-bearing strata of Canterbury from the Waitaki to the Hurunui belonged to the same formation. In 1872 he came to the conclusion that, while the Shag Point coalfield belonged to the Cretaceo-tertiary period, the same coals farther to the north-east were of younger date and belonged to a Tertiary formation (Report on Shag Point District: Geological Reports, 1873–74); and in 1879 ("Geology of Canterbury and Westland"), recognising the latter as the Oamaru formation of Professor Hutton, he referred to it the coal-bearing rocks of Canterbury south of the Rangitata River, and, as a consequence, in his classification of the rocks of the provincial district he dissociated these South Canterbury beds from the coal-bearing sequence of the Waipara and the Malvern Hills. Excepting that he says that the fossils from the greensands over the coal in the Timaru district are not characteristic, he gives no sufficient reason for the alteration which such a change of opinion implies; and, if he recognised stratigraphical and lithological difficulties in the district between the Kakahu and Pareora Rivers, and even farther south, such Gordian knots, if they would not untie, could at least be cut.

The similarity of the general sequence of the younger formations, including the Cretaceo-tertiary, in North and South Canterbury, could in nowise escape his notice; neither could the remarkable correspondence of the rocks of the Waipara and Weka Pass sections with those of the Kakahu and the Waihao fail to throw doubt on the propriety of regarding the beds in the two districts as belonging to formations separated by an unconformity and a considerable lapse of time.

The calcareous sandstones of the Kakahu and the Weka Pass, in the character of the material forming them and in fossil contents, so correspond that it is hard to say why they should be referred to distinct formations; and in both localities this rock is underlain by a nearly equal thickness of what must be regarded as a representative of the Amuri limestone. The Amuri limestone nowhere abounds in fossils, and at the Kakahu scarcely more can be said of it than applies at the Waipara and in the Weka Pass. Characteristic greensands underlie the Amuri limestone in both localities, but those in the northern localities named yield no fossils with the exception of a few shark-teeth and teeth of other fishes. In southern Canterbury there is a greater abundance of fossils in these greensand beds; but, unfortunately, the genera to which they belong, and even it is said the species, have a Tertiary facies; yet in contending for the Tertiary age of these beds this seems to have been overlooked—viz., that, until fossils of a different character have been found in the north, those of the Kakahu and the Waihao must decide the age of the

greensands in the Weka Pass and at the Waipara. The only alternative is to regard these greensands as belonging to different formations, and this has been adopted, with what justification I shall now proceed to show.

So far, the thickness of the beds yet referred to is much the same in all the localities mentioned; but the beds below the greensands have a variable thickness in different localities. In the Weka Pass the thickness of the greensand is not greater than in some parts of the Waihao Valley, and, although in the Middle Waipara section the greensands appear to have a greater thickness, this is due to the direction of the section exposed by the action of the river, being for some distance along the strike of the beds. Underneath the greensands the next beds, if present, are the saurian boulder-beds. These, as regards their thickness, are variable; yet of their being unconformably overlain by the greensands there is no evidence, but much to the contrary, and the idea of unconformity seems never to have presented itself to any observer except Professor Hutton, and even he admits conformity at the Waipara and Weka Pass. These saurian beds are formed of arenaceous sands, in which lines of concretionary boulders indicate the dip of the strata in sections in which they are exposed. These septaria or concretionary boulders are of varying size, and in them the saurian remains are usually enclosed. They by no means always contain saurian bones, but as frequently fragments of fossil wood, and sometimes shells. In a few instances shells and saurian bones have been found together in the same boulder. These boulders are of large size in the Malvern Hills, but, if anything, they enclose shells or fossil wood only. Farther to the south they are by no means absent, and where they occur in the Upper Kakahu they contain a large species of oyster; but, lacking the saurian remains that distinguish them in the Waipara section, the palæontological proofs of their Secondary age may be said to be less satisfactory. In the Waihao section the boulders are comparatively small, and occur also in the lower part of the greensands, and partake of the character of the beds in which they occur. These greensands may rest on quartzose sands and grits of no great thickness which interpose between them and the coal; or, as in some sections, an expansion of the more arenaceous beds below the greensands may take place, and in such cases the sands contain concretionary boulders resembling those of the Waipara saurian beds; or the more calcareous material may take the form of flaggy calc-sandstones in banks more or less continuous. Such rocks are met with at the base of the saurian beds in the Waipara, Malvern Hills, and Kakahu and Waihao Valleys. In the north they are characterized by the presence of the black oyster of the Malvern Hills, Waipara, and Trelissick sections; and in the south by the shell-beds over the coal in the Kakahu, Waihao, and Waitaki Valleys. The coal-bearing beds, consisting

of grits, sands, and fireclays, are almost necessarily, from their character and position at the base of the sequence, of very variable thickness. In the Malvern Hills volcanic detrital material has added greatly to the average thickness of the beds; while farther to the south, as in Otago, the lowest beds, consisting of coarse breccias, graduating upwards into conglomerates, grits, and sandstones, exceed in thickness the entire sequence as seen in the Waihao district of southern Canterbury.

In the Oamaru district, North-east Otago, the sequence does not differ from what has been described, except that between the greensand and the Oamaru building-stone (equivalent to and representing the calcareous sandstones of South Canterbury and the Weka Pass) fragmental volcanic material known as the Waireka tufas are largely developed, and the Amuri limestone is either absent or represented by marly clays.

With respect to the fossils of the shell-beds underlying the saurian beds, the collections made by Dr. Von Haast from the Malvern Hills and Waipawa beds impressed him strongly that the beds, though overlain by strata containing saurian remains, were yet of Tertiary date; and he notes the total absence of ammonites, belemnites, Inoceramus, and such other genera as are expected to be present in Cretaceous deposits. Nor have succeeding collectors been more fortunate, and such characteristic forms of Mollusca have even now to be collected. In this respect these beds have no greater claim to be regarded as of Cretaceous age than those of South Canterbury which occupy the same relative position between the calcareous sandstones and the coal. Saurians have not been collected from the overlying beds in the Malvern Hills, nor anywhere in Northern Canterbury, except in the Waipara Valley and at Motunau. That the South Canterbury beds yield no Secondary forms of Mollusca, or other fossils characteristic of the Cretaceous period, is no more fatal objection than may be urged as disproving the Secondary age of the Malvern Hills beds, and of the lower beds in the Trelissick Basin. The question that will have to be considered is, What correspondence is there between the shell-beds of the Malvern Hills and those that first overlie the coal in South Canterbury? This has yet to be determined; but, so far as I am able to judge, a considerable portion of the shells will be found to be the same, and those that are not are not likely to invalidate the conclusion which the correspondence of the strata and the succession of the different beds indicate. The correlation of these lower shell-beds is a subject which cannot be effectively disposed of until exhaustive collections from the Waipara and lower beds of the Trelissick Basin have been made, such collections being of importance as likely to prove what is already unmistakably indicated—viz., that as the beds are followed southward along the east coast of the South Island they gradually lose the characteristic Secondary fossils present at Amuri Bluff,

yet retain species in common sufficient to show that the Waipara and Malvern Hills beds are the same as at Amuri Bluff; while farther to the south, although there is again a difference in the Kakahu and at the Waihao, this is not sufficient to warrant the separation of the beds in the last-named localities from the lower shell-beds of the Malvern Hills, although were the comparison made with the shells of the Amuri Bluff section there might be some reasons for doing so.

The preceding remarks state the case, and I think, fairly, as this stands between Sir Julius von Haast on the one hand and the directors and officers of the Geological Survey on the other; but there is yet another and an entirely different view taken of the relation of the Kakahu and Waihao greensands, agreeably to which it is attempted to be shown that these greensands overlie unconformably the calcareous sandstones admitted to be the equivalents of the Oamaru limestone (Ototara stone) in North-east Otago and of the Weka Pass stone in northern Canterbury.

In 1873, Professor Hutton, reporting on the geology of the north-east district of the South Island, and in the catalogue of the Tertiary Mollusca and Echinodermata of New Zealand, divided the Oamaru formation into two groups of strata—viz., the Trelissick group and the Ototara group. To the first of these he referred the shelly limestones and calcareous sands that in northern Canterbury are separated from the Weka Pass stone by the Grey-marls, and included in the same group the calcareous sandstone and underlying beds of the Trelissick Basin. To the Ototara group were referred the Weka Pass stone (Weka Pass lower), and the calcareous rocks of the district around Oamaru, comprising the Ototara limestone and the Hutchinson's Quarry beds: thus the Oamaru rocks in the south were all referred to the older or Ototara group.

The main features of this arrangement were retained in his classification of the formations of Otago in his report to the Provincial Government of 1875; but he now recognises the existence of the Trelissick group in the Oamaru district of Otago, and considers the greensands of Otepopo as part of this. The Pareora formation, the intermediate Ahuriri formation being absent, he concluded was unconformable to the Oamaru formation, and as much younger as Upper Miocene deposits are in comparison with Upper Eocene. In thus correlating the Ototara limestone with the Weka Pass stone he agreed with Dr. Hector and differed from Dr. Von Haast, but he agreed with the latter respecting the age of the Oamaru and South Canterbury rocks referred to the Oamaru formation, and considered them to be of Tertiary date (Upper Eocene). Dr. Hector at that time and till now has ever regarded the Hutchinson's Quarry beds as of Upper Eocene age, but the Ototara limestone he refers to the younger deposits of the Cretaceo-tertiary period, and since 1862 has maintained the

infraposition of the greensands, grits, and coal-beds west of the limestone scarp near Oamaru and along the Waitaki Valley.

The greensand beds were collected from by Mr. Traill at Hampden (Onekakara), and possibly also in the Waireka Valley (Trans. N.Z. Inst., Vol. II., pp. 166–69). Part of his collections were examined by Professor Hutton, and noted or described in the Catalogue of Tertiary Mollusca issued in 1873. He referred the fossils to the Upper Miocene period, and the beds to the Pareora formation, classifying them as being younger than any part of the Oamaru formation, and unconformable thereto.

Prior to the issue of the first Catalogue of the Colonial Museum in 1870, the Director of the Geological Survey received a collection of fossils from the Kakahu River, South Canterbury. The collector seems to have paid little attention to the nature of the rocks from which most of the fossils were obtained, and the description of this in the Catalogue would (though not necessarily) imply that the fossils came from the calcareous sandstones representing the Weka Pass stone. In 1873 Professor Hutton, having examined these fossils, referred the beds yielding them to the Pareora formation, without however being aware that they were overlain by limestone belonging to an older formation, the fossils alone being relied on in determining the age of the beds. In 1873 Dr. Hector examined the younger beds along the east coast of the South Island, from Cape Campbell to the Trelissick Basin, and came to the conclusion that all the beds overlying the brown-coal formation and saurian beds of the East Coast up to and including the Weka Pass stone and Grey-marls must be referred to one sequence of strata, now called the Cretaceo-tertiary series.

With this were not included the upper calcareous and shelly beds of the Weka Pass, of the Dean's Range and Mount Brown, on the south side of the Waipara, nor the calcareous greensands and altered limestones of Hutchinson's Quarry in the neighbourhood of Oamaru. These beds, as they had yielded most of the fossils which were referable to the calcareous sandstones of the east coast of the South Island, were still held to be of Upper Eocene age, the age assigned them by Professor Hutton, and, in the classification of 1877, were called the Mount Brown and Hutchinson's Quarry beds. These represented the Trelissick group of Hutton's Oamaru formation, and did not prejudice his palæontological determinations, seeing they were referred to the same period and age. But in dealing with the Ototara group the matter was different. This had to be placed with a series of beds between which and the calcareous rocks of the Ototara group Professor Hutton believed an unconformity interposed.

Agreeably to the requirements of this classification, the greensands, saurian beds, and coal-bearing strata of the Weka Pass, Waipara, and Malvern Hills had to be correlated with a similar sequence of rocks developed along the east side of the Trelissick

Basin, which Professor Hutton referred to the Trelissick group of his Oamaru formation. The South Canterbury rocks conformably underlying the Weka Pass stone, and those of north-eastern Otago in like position under the Oamaru limestone, had also to be referred to the Cretaceo-tertiary series; and farther to the south the beds at Hampden and Moeraki, included by Professor Hutton in the Pareora formation, had to be regarded as the equivalent of, or but slightly higher in position than, the greensands of the Waipara and Malvern Hills sections.

To all this, and much more which became a necessary consequence of the adoption of the scheme of classification sketched by Dr. Hector, Professor Hutton by no means agreed, and the differences of opinion which thus arose are as broadly marked now as they were ten years ago.

In 1875 Dr. Von Haast sent to the Otago Museum a collection of fossils, in all sixty-eight species, from four localities in South Canterbury—viz., White Rock River, Pareora district; Mount Harris and Point Hill, between the Waihao and Waitaki Rivers; and from certain greensands exposed at the Waihao Forks, seven miles south-west of Waimate. At his request Professor Hutton named the collection, describing the new species which it contained, and in doing so referred the whole to the Pareora formation (Trans. N.Z. Inst., Vol. IX., p. 593). This reference was correct with regard to the three first-mentioned localities; but, with respect to the Waihao greensands, in "The Geology of Canterbury and Westland" Dr. Von Haast points out that these underlie the Waihao limestone, a representative of the Ototara stone, yielding, according to his account, all the characteristic fossils of the Oamaru formation. This relation to the Waihao limestone showed him that these greensands could not belong to the Pareora formation, and makes it now equally clear that they belong to the Cretaceo-tertiary series of Dr. Hector. Professor Hutton made the same mistake in 1873 and 1875, when dealing with the fossils from the Kakahu and Hampden—*i.e.*, he referred Cretaceo-tertiary beds to the Upper Miocene period.

In the early days of the Canterbury Geological Survey, as has already been mentioned, the coal-beds of southern Canterbury were considered by Dr. Von Haast to be of the same age as the Malvern Hills coal-beds. In 1879 he referred the latter, and all the strata of the same age north of the Rakaia, to the Waipara or Cretaceo-tertiary formation, and the coal-beds of South Canterbury to the Oamaru formation. He says, however, that "there are a few localities south of the gorge of the Rakaia which, judging from the impressions of leaves, might be referred to this [the Waipara] formation—as, for instance, some beds of shale on the southern bank of the Kakahu, and some small outliers with seams of brown coal between the Opihi and the Opuha. I have thought it more convenient not to separate these outliers from the next [or

Oamaru] formation, by which they appear to be overlain conformably;" and further, when speaking of the age of the Oamaru formation, he says: "I wish to point out another difficulty, the solution of which is of considerable importance for the classification of the beds in question. In the greensands of the Kakahu and the Waihao a number of fossils have been collected by me, which Captain Hutton places with the Pareora formation, as, for instance, *Turritella ambulacrum* and *Pleurotoma buchanani*. These greensands are overlain by calcareous greensands with all the characteristic fossils of the Oamaru formation, on the edges of which the Pareora formation reposes unconformably; consequently a careful study of the more extended collections from these beds is needed to settle this point to my satisfaction."—("Geology of Canterbury and Westland," p. 135.)

In November, 1876, I examined the Kakahu section, and made a considerable collection of fossils from the beds under the greensands between these and the coal-seam exposed in the same section; and last year (1885) Mr. James Park examined the same section, the Upper Kakahu section, and sections of the same beds exposed to the south-west along the Opihi and Opuha Rivers. We both agree with Dr. Von Haast that the sequence shows no unconformity between the calcareous sandstones and the coal-beds; but, recognising the calcareous sandstones as the equivalents of the Weka Pass stone, we refer the whole to the Cretaceo-tertiary series, and we cannot understand on what grounds the greensands and limestones are referred to the Oamaru formation unless this be regarded as a synonym of the Cretaceo-tertiary series. What is of more importance in the present connection is the fact that Dr. Von Haast has no doubt as to the equivalency of the Kakahu and the Waihao greensands; and the facts fully justify this determination.

In October, 1880, accompanied by Mr. Park, of the Geological Department, I spent about three weeks examining and collecting from the fossiliferous rocks of the Waihao basin. The Pareora beds forming Mount Harris were closely examined, and a very considerable collection of fossils obtained from that locality. We also collected largely from the limestones under the Pareora or Mount Harris beds, and from beds of more doubtful position where the Waihao leaves the hills and enters upon its lower course across the coastward plain. These latter I considered at the time as representing the Grey-marls of the Geological Survey classification; but I am now inclined to consider them of older date, and would refer them to a position below the Ototara limestone. At the bridge crossing the Waihao, south of where Arno Railway-station now is, and two miles below the Waihao Forks (Waikakahi Bridge), we made collections from grey sandy beds, getting darker and greenish as they follow downwards till they rest on the greensands of the Waihao Forks. A collection was also

made from boulders occurring in the greensands at the Waihao Forks, and from one or two localities where the same or lower beds are exposed. The result of our stratigraphical examinations was the conclusion that the greensands did in the most unmistakable manner pass under the calcareous sandstones known as the Waihao limestones. We did not for a moment entertain the idea that any one having examined the sections could believe that the greensands were younger than the limestones, and, although the collections contained some fossils that have been considered to indicate the Miocene age of the beds in which they are found, we did not think that these could in the least lessen the force of the stratigraphical evidence. It was also manifest that neither the rocks nor the fossils of Mount Harris corresponded with the greensands and their fossils as seen along the banks of the Waihao River—a further proof that the latter are not of Miocene age or part of the Pareora formation.

On the 31st January, 1885, Mr. A. B. Lindop, C.M.E., reporting on the Waihao coalfield, says, "The coal-measures are first seen cropping to the surface at McCulloch's Bridge, about two miles below the forks of the river; and there consist of dark-coloured shales dipping to S.W., at low angles, underneath the limestone." Mr. Lindop therefore agrees with Sir Julius von Haast, Mr. Park, and myself that the beds seen in the river-bed between McCulloch's Bridge and the Waihao Forks pass under the limestone, and it would be matter for some surprise should it prove that all four of us have been mistaken on a subject respecting which not a doubt seems to have been entertained at the time when the different observations were made.

Both at the Kakahu, and in the district south of the Waihao to the Waitaki River, the Pareora series is developed as grey or brownish arenaceous sands, sometimes having a greenish tinge, but in no case do they assume the intense almost black colour of the Kakahu and Waihao greensands. In the Kakahu district the beds of this series always rest on the limestones belonging to the Cretaceo-tertiary series, and are never found as outliers to the westward of the older series.* They are almost always richly fossiliferous, and alike by their mineral character, stratigraphical position, and fossil contents are easily distinguished from the greensands and coal-beds under the limestones.

In his report on this district Mr. Park says: "During the progress of my work fossils were collected from the Pareora beds and from the coal greensands. Fossils are very abundant in both and very characteristic of their respective formations, and it is very interesting to find typical Pareora beds present in a section in which the coal-measures, with their fossils, are so well de-

* Towards Pudding Hill, Waihao Valley, there are outliers of Tertiary beds, but these appear to be older than any of the beds that are fossiliferous in Mount Harris.

veloped as in the Kakahu Valley."—(Geological Reports, 1885, p. 174.) The reason why no lists of Kakahu fossils are given is that the fossils of the lower beds could only be named generically, and, in the case of some that have been named specifically, names common in lists of Tertiary fossils would have to be applied to fossils that to some extent resemble, but are not identical with, the type specimens described from younger beds. *Turritella ambulacrum* is a very good instance of this. The Kakahu specimens, whether as casts or the perfect shell, are not unlike the type from the Awatere in the Colonial Museum where this is testiferous, but as casts the Awatere specimens differ considerably from those from the Kakahu. In the one case the ridges on which the specific distinction is founded are external only, the whorl in the cast being smooth and flat; in the Kakahu specimens the casts are as strongly marked, and in the same manner as the exterior surface: therefore, till such distinctions have been duly considered, and the new species named and described accurately, mere lists of generic names are to little purpose. However, it does not follow that the collector is unable to make out a sufficient distinction in the facies of the collections made—a distinction which the stratigraphical positions of the beds collected from fully warrant. Long experience has taught me that it is not necessary to be able to name a collection throughout in order to refer it to its proper place in the sequence of formations in the district from which it comes, and, although additions to knowledge are advantages to be sought after, they should not be sought for along a single line; and in cases like the present, where the stratigraphy leaves no room for doubt, palæontological niceties must be dispensed with. The discovery of a fossil species in what appears to be the wrong place does not so much require that the stratigraphical arrangement be accommodated to the palæontological fact as that some modifications of our palæontological views be made; and I can safely affirm that, in more than one instance, as regards New Zealand geology, the rigid facts of superposition and stratigraphical succession will compel the sister science to take its proper and subordinate position.

So far as stated, the testimony of the field observers is decisive as to the position of the calcareous sandstones of South Canterbury relative to the Pareora formation, and this testimony is equally decisive as to the inferior position of the Kakahu and Waihao greensands. Professor Hutton on palæontological grounds was led to refer these greensands to the Parcora formation, seemingly unaware that the calcareous rocks of the Oamaru formation separated them from the Pareora formation in the same district; and during the ten years succeeding 1875 neither the expressed opinion of Dr. Von Haast nor the results obtained by other geologists seem to have shaken his opinion respecting

what should be the position of these beds. In December, 1885, he paid a visit to the Waihao Valley in order to ascertain upon what grounds the alleged inferior position of the greensands to the limestone rested, or, in other words, "to clear up the difficulty;" and on the 6th May, 1886, he read a paper before the Philosophical Institute of Canterbury (Trans. N.Z. Inst., Vol. XIX., p. 430), in which he recognises the Waihao limestone as belonging to the "Oamaru" formation, but arrives at the singular conclusion that the Waihao greensands are younger, and form part of the Pareora formation. It is to be presumed that all the more important sections displayed in the district were examined; yet, speaking of the greensands, he says, "In no case are they seen to pass under the marl [that above there underlies the limestone] or to lie upon it." This is so much at variance with the conclusions of all other observers, and in itself a statement so positive, that it requires to be supported by proofs equally decisive and incontrovertible; and, if true, the conclusion is unavoidable that at least four geologists (Dr. Von Haast, Park, Lindop, and myself) have imagined they saw that which cannot be seen. Ours, however, is testimony of a positive character; Professor Hutton's is simply that he did not see.

The issues of this discussion have already been indicated, and they are of far greater importance than the simple determination of the position of the Waihao greensands. Here we have, as it were, centred upon one point all those burning questions which, as regards the younger strata of New Zealand, have required settlement since 1873. If it be here proved that the Waihao greensands underlie the limestones, there need be no further dispute respecting the beds at the Kakahu, or the same beds in the Waireka Valley, at Otepopo, Hampden, Moeraki Peninsula, in the district from Palmerston to Waikouaiti, or in Shag Valley; but, if the Waihao greensands overlie the limestones and belong to the Pareora formation, the Cretaceo-tertiary is stripped of its basement-beds, and the Shag Point coalfield itself must be referred to the Upper Miocene period. What then would be the age of the unconformably younger beds, now referred to the Upper Eocene, between Shag Mouth and Waikouaiti; to what time should we refer the greatest extension of Post-miocene glaciers in the South Island; and to what period in the future should the existing Wanganui formation be assigned? Truly, I dare not venture on such revolutionary measures; rather would I put the Waihao greensands under the limestone, and abide by the lesser consequences.

Professor Hutton describes the beds and sequence of the Oamaru formation in the Waihao Valley as follows: "The right bank of the Waihao River, from a little above the Forks down to the bridge by which the road from Arno to Waikakahi crosses the river—a distance of about three miles—is formed by rocks of the

Oamaru system. A northerly extension of these rocks, rather more than a mile in breadth, crosses the river about half a mile below the Forks; so that for this distance the Oamaru system forms both banks of the river. . . . The rocks belonging to the Oamaru system here are: 3. Pale-yellow arenaceous limestone, about 50ft. thick, known as the Waihao limestone [?]. 2. Calcareous sandstone with green grains, 150ft. 1. Dark-grey marl, getting more sandy at the top, with ferruginous bands or veins; thickness, 50ft. . . . No rock is seen to underlie this marl anywhere between the forks of the Waihao and its mouth."

The other rocks of this part of the Waihao Valley are thus described: "On the left bank of the river, both above and below the northerly extension of the Oamaru system, we find thick (200ft.) beds of soft dark-green or grey argillaceous sandstone, sometimes with calcareous concretions, and containing numerous fossils." Excepting those of Palæozoic age on which the younger system is seen reposing on the north side of this part of the valley, the above description suggests the idea that no other rocks can be seen on either bank between the Waihao Forks and the point where the river enters upon the shingle-plains. The greensands claimed to belong to the Pareora formation are never found resting upon the older rocks, and, if the beds upon which they rest do not also belong to the Pareora series, stratigraphical evidence proving an unconformity might have been expected along the junction-line, or seen in some of the many sectional exposures within a short distance of the Waihao Forks. The proof of such an unconformity between the greensands and the coal would have told strongly in favour of Professor Hutton's theory, and, though not decisive unless the coals were shown to belong to the Oamaru formation, would yet have been evidence in favour of the Pareora age of the greensands.

An unconformity in this position would have quite a different bearing on the question at issue from that I endeavour to prove at the upper surface of the greensands in the Elephant Hill section, and would be strong evidence that the greensands do not pass under the limestones.

There is also another line of inquiry which seems not to have been entered upon, or even thought of. It is this: If the greensands are actually younger than the limestones and belong to the Pareora formation, even though not actually seen resting upon the limestone, they ought to be exposed in the banks of some of the several small streams flowing north from Mount Harris. They also ought to be exposed in the road-cuttings south of Waikakahi Bridge, for it could scarcely be that a series of beds that along the present course of the Waihao are some 200ft. thick, and on its northern bank rise to a greater elevation than the limestone on the south bank, should be wholly absent from the country farther south, more especially as these greensands

would have to be referred to the lower part of the Pareora series. Yet Professor Hutton's stratigraphical inquiries extend no farther than the two banks of the river from the Waihao Forks to the eastern slopes of the Waimate Hills; and, content to believe that the palæontological evidence is decided and sufficient, he says, "The stratigraphical evidence is not so satisfactory, for no clear sections exist." The section illustrating his paper looks decisive enough, even though it be accepted as being, "to some extent, hypothetical." He says, "There is no difficulty at all in supposing these Pareora rocks cross both the south and north branches of the Waihao." The answer is, None whatever; and yet the question is, Do they? The greensands are certainly found as indicated; but, as showing whether these be Pareora rocks or not, I may be allowed to quote a passage from "The Geology of Canterbury and Westland." Describing the rocks of the Oamaru formation as developed in the Waihao Valley and at Elephant Hill, Dr. Von Haast says: "White underclays, 30ft. to 40ft. thick, form here the lowest beds of the Oamaru formation; then follows, in ascending order, a seam of brown coal 12ft. thick. . . . . Above this seam of coal sharp white quartz-sands, about 10ft. thick, lie, which, in descending, run gradually out, and fireclays, about 6ft. thick, take their place, reposing directly upon the coal. Then follows a characteristic bed of quartz conglomerate or pebble-bed, with a highly ferruginous matrix, consisting sometimes of more or less angular pieces of slates, sandstones, and rounded pebbles from the Waihao formation. This bed varies very much in thickness; in some districts it is only a few inches thick, in others 30ft. . . . Quartzose sands follow, gradually altering to greensands, with Cucullæa, Turritella, *Pecten hochstetteri*, *Scalaria lyrata*, and *Waldheimia lenticularis*. In their upper portion these sands become so filled with grains of glauconite that the rock looks quite black. They are succeeded by clay-marls, altering to calcareous greensands. These characteristic rocks are sometimes massive, sometimes divided into banks by layers of a more calcareous nature, the latter standing out as protuberances. In some localities they are quite full of grains of glauconite; in others this mineral is less frequent. Fucoid casts are common; in other places the whole rock appears to consist almost entirely of minute pieces of corals, echinoderms, and shells." Though concise, so just and complete is this description that I forbear giving any other.

In the same work the Pareora formation is described as generally reposing on the edges of the Oamaru formation, or, where the latter occurs in basins, towards the centre of the basin. Its principal beds "consist mostly of bluish or greenish argillaceous sands, with harder calcareous, mostly fossiliferous beds, interstratified." As in the north, so also in the southern part of the Canterbury District, this lower fossiliferous part is overlain "by beds of conglomerate, mostly formed of small river-shingle, deposited in a

shallow estuary, and consisting mostly of the *débris* of the Palæozoic ranges. . . . . There is a great similarity in the rocks belonging to this formation, [and] the occurrence of small beds of lignite in them is only an exception. . . . . Between the lower course of the Waihao and Waitaki the low hills bounding the Waitaki Plains are formed of Pareora beds of considerable thickness."

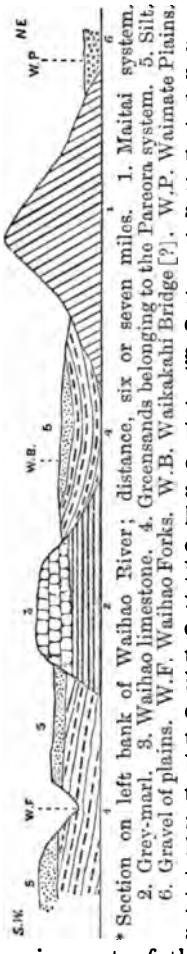
During the month of June last I had an opportunity of visiting the Waihao Valley, and, though my examinations were made mostly within that part of the district examined by Professor Hutton, I had no difficulty in finding sections that appeared quite conclusive as respected the position of the greensands to the overlying marls and limestone. These examinations commenced at the Waihao Forks, where the greensands are clearly exposed in the banks of the river, in the railway-cutting on the left bank, and at the west end of the patch of limestone on the north bank of the river below the Forks. This outlier from the main body of the Waihao limestone is somewhat more than half a mile in length. It forms a line of cliffs on the side facing the river, and on the northern side forms a steep slope to the level of the plain opposite Arno Railway-station. The hill-slope on this side does not clearly show the limit of the limestone, except at the southern end, where the road from the railway-station crosses the saddle to the bridge over the Waihao; but its breadth may be estimated at from 50yd. to 100yd. As the limestone forming the crest of the ridge has been subjected to denudation, I estimate its average thickness at from 50ft. to 80ft., and it is not more than 100ft. under the highest part of the hill where it is thickest. On the south side of the ridge the slope to the river is covered with large blocks of the limestone, which, on the removal of the underlying greensands and marl, have broken away from the main body of the limestone *in situ*. In this manner the present line of cliffs has been formed. The greensands can be traced down the river till abreast of the north-western end of the limestone ridge; and, although they cannot be clearly shown to underlie the limestone at this place, the inference is that they do. The greensands showing in the river-bed pass under grey marly beds having a sprinkling of green grains, corresponding to the "dark-grey marl" described by Professor Hutton as the lowest member of the "Oamaru system," as seen in this part of the Waihao Valley.

These marly beds again show under the limestone before reaching the bridge two miles below the Forks, and, although there is some obscurity in the section between the exposure of the marl and the bridge, from the disposition of the strata, it does not appear to me as doubtful that the higher part of the marly greensands underlies the marl, and, with it, passes under the limestone on the south bank of the river. Just below the bridge the higher part of the marly greensands is grey or dark grey in colour, in

this differing from the almost black greensands seen lower in the sequence, and which are well exposed at and above the Waihao Forks, in each of the branches of the river; and again in the ridge of hills east of Arno Railway-station. Where indicated in Professor Hutton's description of the beds, and where shown in the section illustrating his paper, I sought for evidence in proof of his theory that the Oamaru formation in the low grounds had been denuded in such a manner that vertical cliffs were formed, along the base of which the greensands were deposited at a lower level than the limestone, so as, in places, to imply that the greensand might pass beneath the limestone; but I failed to observe any facts that could be used in support of such a theory.

Having entered upon the investigation of the evidences of this theory, my attention was forced to the consideration of one or two facts that are hardly in accord with its requirements. The formation of the principal escarpment must date back to Middle Miocene times, and, as the greensands seem yet to abut against the base of the limestone cliffs, no erosion of the cliff face, no retreat to the south, can have taken place since the deposition of the greensands. Yet the cliffs are now ruinous, and formed of material subject to rapid disintegration, and therefore the greensands should nowhere approach them within a considerable distance. The contrary is the fact, and it is admitted that the greensands lie close to the limestone from the Waihao Forks for at least half a mile down the river. Then, again, if the "Oamaru system" from half a mile below the Forks is found on both banks of the Waihao, the river in cutting down through the higher beds of the Oamaru formation should not in this part of its course have exposed the greensands; yet such is the case, and the same fossils that may be gathered in plenty from the higher part of the marly greensands below the bridge, on the road to Waikakahi, are abundant under the limestone on the south bank of the river opposite the western end of the limestone on its northern bank. The limestone on the north bank of the river gives ample proof of the rapidity with which it is being removed, since, through the removal of the softer beds at its base, and the marl underlying along the whole line, the limestone has given way, lessening the breadth of the limestone *in situ* 50ft. or 60ft. at a time, and this at such short intervals that the whole slope to the river-bank is strewn with masses of limestone such as indicated, and therefore no greensands should be seen near the limestone on this side of the river; yet the fact is witnessed by Professor Hutton's own section, the greensands being shown in contact with the limestone. This section, commencing at the Waihao Forks, follows the left or north bank of the Waihao to the seaward plain on the east side of the Waimate Hills. That part of it showing the greensands between the lower slopes of the Waimate Hills and the east end of the limestone on the north bank of the river I take the liberty of

reproducing, as there is an important difference in my reading of the same section :—



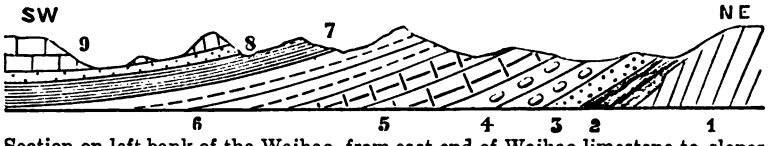
* Section on left bank of Waihao River; distance, six or seven miles. 1. Maitai system. 2. Grey-marl. 3. Waihao limestone. 4. Greensands belonging to the Pareora system. 5. Silt. 6. Gravel of plains. W.F. Waihao Forks. W.B. Waikakahi Bridge [?]. W.P. Waimate Plains.

Beds No. 1, referred to the "Maitai system," are to the south-west overlain, as shown in the section, by the Waihao greensands, said to belong to the "Pareora system," and farther to the south-west these are shown resting with unconformity on the Waihao limestone and the underlying Grey-marl, Beds Nos. 3 and 2. The greensands again appear at the western end of the limestone, and thence are continuous to the Waihao Forks.

As given by Professor Hutton this section does not show the quartz-sands and lower shell-beds underlying the greensands, nor the ferruginous quartz-grits, shales, fireclays, and coal-beds that are present between the east end of the Waihao limestone and the south-west slopes of the Waimate Hills. The beds mentioned occur there, and were examined and collected from when I visited the district six years ago. I paid at that time some attention to the lower beds, as there was some promise of a coal-seam occurring in the lower beds, and as from the overlying semi-crystalline calc-sandstones I obtained a number of fossil fruits. These beds reach a height of 400ft. on the slopes of the Waimate Hills; and to the westward in the middle of the syncline shown by Professor Hutton the greensands overlying are exposed, laid bare by a slip on the hill-side facing the Waihao. The darker greensands are followed by those of lighter colour seen on the right bank of the river at Waikakahi Bridge, and, though the clay-marls are not so clearly displayed, since the next bed overlying them shows itself on the saddle just where the main mass of the limestone begins, it is hardly likely that this bed is absent; but, if so, its absence would have to be accounted for by the thinning-out of the bed in this direction. As, however, Professor Hutton agrees with me that this marl-bed underlies the limestone, I need not proceed with the demonstration of its inferior position.

I disagree with him entirely in his view that the beds form a syncline between the east end of the limestone and the south-west slopes of the Waimate Hills. They are disposed as represented in the following section :—

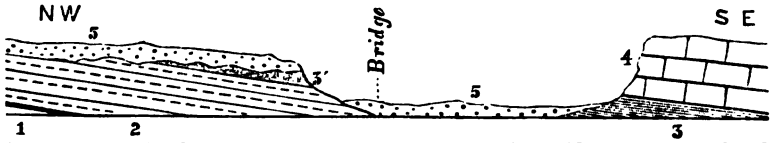
* Copied from Professor Hutton's Paper on Geology of the Waihao Valley.



Section on left bank of the Waihao, from east end of Waihao limestone to slopes of Waimate Hills. 1. Maitai slates and sandstones. 2. Fireclays and coaly shales without any distinct coal-seam. 3. Quartzose grits. 4. Grey sands with concretions and beds of calc-sandstone. 5 and 6. Waihao greensands—lower and upper parts. 7. Clay-marls (?). 8. Loose, slightly calcareous greensand, brown or yellowish-brown. 9. Waihao limestone.

The dip of the beds being to S.W. (though this becomes W. to the north-west and S. to the south-east of the line of section), in crossing to its south side the outcrop of the higher part of the marly greensands descends the ridge of hills in a south-west line, and crosses the river a little below the Waikakahi Bridge. The division is marked by a hard band of more calcareous rock, and scarcely any concretionary boulders are found in the upper part. Almost the highest bed seen, close to the bridge, is a thin band of calcareous rock, which indicates the dip as W. or W.S.W. at an angle of 10°. Above the bridge the section is obscure for a distance of about 5 chains, and the next rock that is seen is the clay-marls dipping at a low angle underneath the limestone.

Here, therefore, it may be said that all kinds of possibilities may have taken place within the 5 chains distance over which the section is obscure. I submit the section and its evidence as given in the woodcut below, and do not venture to assert what the correct reading of it should be :—

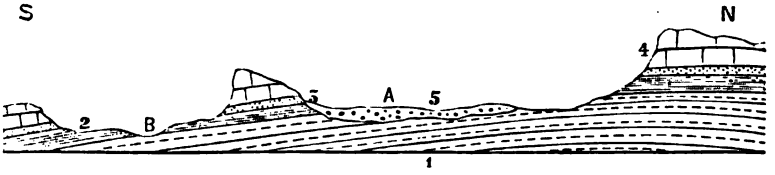


Section on right bank of the Waihao at Waikakahi Bridge. 1. Hard band separating upper and lower parts of the marly greensands. 2. Upper part of marly greensands. 3. Clay-marls. 3′. Possibly the lower part of 3. 4. Waihao limestone. 5. Terrace-gravels and recent river-shingle.

As mentioned by Professor Hutton, the Waihao limestone and beds underlying it cross the Waihao half a mile below the forks of the river, and, as described, the limestones extend down the river a distance of about half a mile, as the highest beds of a flat syncline. Certain lines of section would tend to show some such arrangement of the strata; others point simply to a southerly dip changing at places to a more westerly direction; but I will assume that there is a synclinal arrangement of the limestones on the left bank of the river below the Forks. In any case, it is absolutely proved by the different elevations above the sea of the limestone on the north and on the south bank of the river that this syncline must be raised towards the north. On this side of the river the limestone forms a narrow ridge, 200ft. to 300ft. wide at most:

its elevation is about 200ft. above the river. The greensands are found in the river-bed opposite both ends of the limestone ridge, and manifestly a considerable thickness of greensands underlies the lowest bed seen. Proof of this may be had in one or other or both branches of the river above the Forks. Professor Hutton supposes that from the eastward, where they fill the valley below Waikakahi Bridge, these greensands not only abut against the limestones in the manner he has shown in his section, but also pass along the north side of the limestone ridge so as to connect with the same beds at the Waihao Forks; but, as immediately the limestones are passed the greensands again recede to the south and show in the banks of the river under the limestone scarp on the south side, and as the fossils of the greensands are found yet farther down the river, where the main body of the limestone is directly opposite the outlier on the northern bank, this would indeed show (always supposing the greensands to be younger) that the present channel of the river was cut to a deeper level than at present prior to the deposition of the greensands; and the limestones on the northern bank, being fully 300ft. above the floor of the valley or sea-bottom, and forming a ridge scarcely broader than high, must have been in the greatest danger of being wrecked altogether.

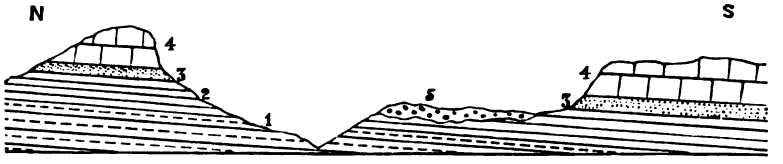
But, though the greensands pass to the north of the limestone ridge, they also pass under it; and the pronounced southerly dip, and the manner in which the greensands connect with those at the Waihao Forks, are shown in the following section, taken north-and-south along the trough of the supposed syncline:—



Section north-and-south across Waihao River, one mile below the Forks. 1. Greensands. 2. Clay-marls. 3. Bed of greensand. 4. Waihao limestone. 5. Terrace-gravels. A. Arno station. B. Waihao.

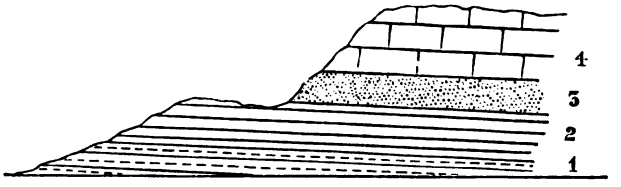
Farther to the north there is yet another outlier of the limestone dipping W. or nearly horizontal, and at a higher elevation than any in the above section; and east of this the greensands, grits, and coal-shales rest on the west slopes of the range towards Waimate.

As there is some exaggeration of the dip in the southern end of the section, the following on a larger scale shows this at not more than it is:—



Section across Waihao in nearly same line as last. 1. Greensands. 2. Clay-marls. 3. Bed of greensand. 4. Waihao limestone. 5. River-gravels.

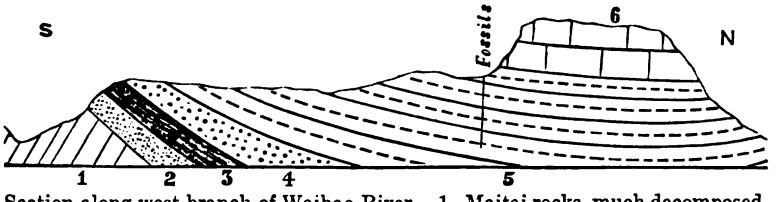
A little higher up the right bank, where a small creek coming from the south-west joins the river, Beds Nos. 3, 2, and 1 may be seen passing under (4), as here represented :—



Section on right bank of Waihao, vicinity of last section. 1. Greensand with characteristic fossils. 2. Marly clays. 3. Bed of loose greensand. 4. Waihao limestone.

Farther up the river, a little before reaching the junction of the two branches, the greensands of the Forks can be seen under the limestone in the different small gullies south of the main stream and feeders of a small creek coming from the south-west, and just at the crossing of the west branch of the river the fucoidal band dividing the greensands into an upper and a lower part may be seen in the river-bed.

The preceding sections I should think are quite sufficient to show what the relation of the Waihao greensands to the limestones in the same district really is, but were more proof required there is no scarcity of further sections and natural exposures showing the inferior position of the greensands and the absolute superposition of the limestones. Of these I give but one more which can be seen on the right bank of the west branch of the river three quarters of a mile above the crossing of the road to Pudding-hill Station.



Section along west branch of Waihao River. 1. Maitai rocks, much decomposed. 2. Quartzose sands. 3. Coal- and shale-beds. 4. Grey sands. 5. Waihao greensands. 6. Waihao limestone.

The section seen at Elephant Hill, as it has little bearing on the question of the position of the Waihao limestone relative to

the underlying greensands, need not be reproduced, as in it the evidence is as to the conformity or unconformity of the Pareora beds to the coal-bearing strata and the beds overlying, and, as I think it cannot longer be doubted that the greensands underlie the limestones, the absence of the limestones in that section sufficiently proves the position I have taken up respecting the relation of the beds above and below the fucoidal band, whereat I place the unconformity between the two series represented.

This section, as represented at page 72 of the Geological Reports for 1881, is something more than what Professor Hutton pleases to call it when he says it is a "hypothetical illustration" of my views, of which to perceive the impossibility the section has only to be looked at. That which is hypothetical in the section as shown is the dipping of the coal underneath the greensands, which was not observed; but the various sections illustrating this report will, I think, justify the theoretical representation of the coal in this position. It may be, however, that I mistake Professor Hutton's meaning, and that what he characterizes as "hypothetical and impossible" in this section applies not to its lower part, but to the junction between the marly greensands and the fossiliferous portion of the Pareora formation which overlies unconformably; but, in this case, if the lower part of the section containing the coal-seam belongs to the formation of which the Waihao limestone is the higher part,—and that it does no one attempts to gainsay,—then, as Professor Hutton contends for unconformity between the Pareora and Oamaru formations, proves it to his own satisfaction, and appeals to the writings of Dr. Von Haast as placing the matter beyond doubt, I fail to see by what law of fair criticism my section should be characterized as it has been. Under such circumstances, had I represented the Pareora beds as resting conformably upon the greensands, supposing the direct proofs of unconformity not very apparent, the section had then been of a more hypothetical character than as actually shown. Many natural sections are seemingly impossible if viewed and judged of according to what is taught respecting the general structure of the district in which they occur, and subject to those conditions I take it Professor Hutton regards my rendering of the Elephant Hill section.

PALÆONTOLOGICAL EVIDENCE.

The palæontological evidence that the Waihao greensands belong to the Pareora formation is not more satisfactory than the stratigraphical proofs. Professor Hutton gives a list of sixteen species of Mollusca supposed to have been collected from the Waihao greensands, nine of which it is said do not occur in rocks older than the Pareroa beds, and all except one—*Leda fastidiosa*—are found in the Pareora beds elsewhere.

The nine species referred to are the following:—

Siphonalia nodosa, *Martyn.*
Ancillaria australis, *Sowb.*
Pleurotoma fusiformis, *Hutton.*
Pleurotoma buchanani, *Hutton.*
Pleurotoma awamoaensis, *Hutton.*
Clathurella hamiltoni, *Hutton.*
Voluta corrugata, *Hutton.*
Natica suturalis, *Hutton.*
Leda fastidiosa, *Adams.*

Siphonalia nodosa comes from the Leda beds of Raglan, Whangaroa clays of Hochstetter—at least a form as much like *S. nodosa* as the Waihao and Hampden specimens are.

Ancillaria australis: I collected seven specimens, which much more resemble *A. fusiformis* of the Lower Eocene of England. None of these approaches *A. australis* in form.

Pleurotoma fusiformis does not appear in the original lists of Waihao fossils (1876 and 1879), and I have not collected it from the greensands. It was originally described from the Pareora beds of Mount Harris.

Pleurotoma buchanani stands in Haast's lists as a fossil of the Oamaru formation from the Waihao, and he specially notes it as a fossil of the greensands.

Pleurotoma awamoaensis may be present, but Dr. Von Haast notes a variety of the species only.

Voluta corrugata appears to be a doubtful determination; it is not mentioned in Haast's list of 1879.

Clathurella hamiltoni: I am not acquainted with this species; it may be present.

Natica suturalis is said to come from Mount Royal, near Palmerston, Otago (Proc. Linn. Soc. N.S.W., 1886, p. 215), where there are no Pareora beds, or marine beds of yet younger date.

Leda fastidiosa, as *L. semiteres,* is mentioned by Haast as a fossil of the Oamaru formation, from the Trelissick Basin. Hutton, in the original description, refers it to the "Waiho" (Waihao). In 1879 Dr. Von Haast refers it to the Pareora formation. Seemingly, therefore, he did not collect it from the Waihao greensands, but from the Pareora beds, between the lower course of the Waihao and the Waitaki, where the beds belong to the Pareora formation ("Geology of Canterbury and Westland," p. 317). The species is recent, and, if correctly identified, reaches into the Oamaru formation in other parts of the South Island: hence the limit of its range is not the Pareora beds.

Of the remaining eight species, *Teredo heaphyi, Dentalium mantelli,* and *Pecten hochstetteri* are common Cretacco-tertiary forms, and, with *Flabellum circulare,* it is not surprising they should be found in the Waihao greensands. *Natica gibbosa,* the same as *N. solida* of former lists, said to be common in beds of the Oamaru formation, I have not collected from these greensands, nor is it noted as coming from the Waihao by Dr. Von Haast; it is simply noted as common in the Oamaru formation. *Ancillaria hebera* and *Natica hamiltoni* come from the older Tertiary rocks of the Trelissick Basin. Thus but two of the sixteen species can be fairly

said to be confined in their range so as not to pass the limits of the Pareora formation and prove the Post-eocene age of the Waihao greensands; and on account of these is the manifest stratigraphical sequence of the strata to be represented at variance with what appears, and has been determined by four out of the five observers who have examined the relationship of the Waihao greensands?

The doubtful character of the palæontological evidence may be further shown by comparing the lists of fossils as these are given by Dr. Von Haast and Professor Hutton at different dates, and by contrasting such lists with those of the Pareora fossils found in Mount Harris, the principal fossil locality of the Pareora formation in the same district.

It is useless and vain to compare the fossils of the Waihao greensands with those of the Pareora formation as a whole, because there are so many localities where the beds are doubtfully of this age, or by the Geological Survey are declared to be of greater age, yet are included in the Pareora formation of Hutton; but, as all are agreed that the Mount Harris beds belong to the Pareora series if the Waihao greensands belong to the same, there should be a decided correspondence of the fossils indicating this relationship. The two localities are not more than three miles apart.

The collection of Canterbury fossils examined by Professor Hutton during 1875–76 numbered sixty-eight species; but of these he gives no complete list in his paper of the 6th of September, 1876. He simply states that, of the total, twenty-two are additions to our Tertiary fauna, the remainder being species already described as found in our Tertiary rocks. In 1879 Dr. Von Haast acknowledges his obligation to Professor Hutton for the "naming and describing" of the collections made by him in southern Canterbury, and it is reasonable to suppose that the lists of Oamaru and Pareora fossils in "The Geology of Canterbury and Westland" include the species named and described by Professor Hutton. In the Proceedings of the Linnæan Society of New South Wales for 1886 Professor Hutton gives a list of all the Pareora and Oamaru fossils known to him. From this I have taken a list of the fossils of the "Waihao greensands," from "Mount Harris" and "Point Hill, Waitaki;" and these, with the list of those from the Waihao greensands already given, appear in the following table; which also shows what fossils from the same beds were known to Dr. Von Haast in 1879.

A number of the species mentioned by Dr. Von Haast have since been given different names, but I have corrected his list, so as to be in accord with the nomenclature at present in use.

Table of Fossils from the Oamaru and Pareora Formations in the Waihao and Waitaki of South Canterbury.

—	Waihao, Haast, 1879.	Waihao, Hutton, 1876.	Waihao, Hutton, 1885-86.	Waihao, Hutton, 1886.	Waitaki, Haast, 1879.	Mt. Harris, Haast, 1879.	Mt. Harris, Hutton, 1876.	Mt. Harris, Hutton, 1886.	Lower Waihao and Waitaki, Haast, 1879.	Point Hill, Waitaki, Hutton, 1886.	Oamaru Formation.	Pareora Formation.	Species noted by Haast.	Species noted by Hutton.
Crocodilus, sp. (Haast)	*			*									*	
Carcharodon angustidens, *Ag.*			*								*		*	*
Aturia ziczac, *Sowb.*; var. australis, *McCoy*			*	*							*			*
Murex neozelanicus, *Quoy and Gaimard*						*		*				*	*	*
Typhis hebotatus, *Hutton*						*	*	*				*	*	*
Fusus australis, *Q. and G.*									*			*	*	*
Fusus dentatus, *Hutton*						*	*	*			*	*	*	*
Siphonalia nodosa, *Martyn*				*							*			*
Siphonalia costata, *Hutton*							*					*		*
Siphonalia dilatata, var. crawfordi, *Hutton*						*						*	*	
Peristerina cincta, *Hutton*			*								*			*
Cominella ordinalis, *Hutton*									*			*	*	
Ancillaria australis, *Sowb.*	?		*	*							*		*	*
Ancillaria hebera, *Hutton*	*		*	*									*	*
Voluta elongata, *Hutton*; not of Swainson	*										*		*	
Voluta gracilis, *Swainson*						*		*					*	*
Voluta pacifica, *Solander*						*		*					*	*
Voluta corrugata, *Hutton*			*	*				*			*	*	*	*
Mitra apicalis, *Hutton*						*			*			*	*	
Mitra enysi, *Hutton*	*											*		
Mitra inconspicua, *Hutton*			*					*			*			
Conus trailli, *Hutton*									*	*				
Conus ornatus, *Hutton*									*	*		*	*	*
Pleurotoma fusiformis, *Hutton*			*	*		*	*	*			*	*	*	*
Pleurotoma buchanani, *Hutton*	*		*	*			*						*	*
Pleurotoma haasti, *Hutton*						*		*				*	*	*
Pleurotoma sulcata, *Hutton*												*	*	*
Pleurotoma pagoda, *Hutton*												*	*	*
Pleurotoma awamoaensis, *Hutton*	?		*	*		*		*				*	*	*
Pleurotoma hebes, *Hutton*					*								*	*
Clathurella hamiltoni, *Hutton*			*	*									*	*
Triton spengleri, *Lamarck*														
Natica neozelanica, *Q. and G.*	*												*	*
Natica suturalis, *Hutton*	*	*	*	*									*	*
Natica gibbosa, *Hutton*			*	*									*	*
Natica hamiltoni, *Tate* (?)				*									*	*
Sigaretus subglobosus, *Sowb.*									*					*
Struthiolaria vermis, *Martyn*									*				*	*
Struthiolaria cingulata, *Zittel*								*					*	*
Trochita dilatata, *Sowb.*														
Trochita neozelanica, *Lesson*	*													
Crepidula striata, *Hutton*	*													
Turritella patagonica, *Sowb.*									*				*	*
Turritella concava, *Hutton*														*
Turritella rosea, *Q. and G.*								*						

TABLE of FOSSILS from the Oamaru and Pareora Formations in the Waihao and Waitaki of South Canterbury—*continued.*

—	Waihao, Haast, 1879.	Waihao, Hutton, 1876.	Waihao, Hutton, 1885–86.	Waihao, Hutton, 1885.	Waitaki, Haast, 1879.	Mt. Harris, Haast, 1879.	Mt. Harris, Hutton, 1876.	Mt. Harris, Hutton, 1886.	Lower Waihao and Waitaki, Haast, 1879.	Point Hill, Waitaki, Hutton, 1886.	Oamaru Formation.	Pareora Formation.	Species noted by Haast.	Species noted by Hutton.
Scalaria lyrata, *Zittel*	*										*		*	
Dentalium giganteum, *Sowb.*											*	*	*	*
Dentalium læve, *Hutton*											*	*		*
Dentalium tenue, *Hutton*	*										*	*	*	*
Dentalium conicum, *Hutton* (var.)	*										*	*	*	*
Dentalium mantelli, *Zittel*			*	*		*					*	*	*	*
Teredo heaphyi, *Zittel*	*		*	*							*	*	*	*
Panopæa orbita, *Hutton*								*			*	*	*	*
Panopæa worthingtoni, *Hutton*						*		*	*		*	*	*	*
Corbula canaliculata, *Hutton*						*	*	*	*		*	*	*	*
Psammobia lineolata, *Gray*										*	*	*	*	*
Psammobia, sp. (Haast)									*		*	*	*	*
Venus stuchburyi, *Gray*									*		*	*	*	*
Dosinia grayi, *Zittel*								*			*	*	*	*
Cardium patulum, *Hutton*			*								*	*	*	*
Cardium spatiosum, *Hutton*						*					*	*	*	*
Crassatella obesa, *Adams*						*		*			*	*	*	*
Crassatella attenuata, *Hutton*										*	*	*	*	*
Cardita patagonica, *Sowb.*								*	*		*	*	*	*
Cardita difficilis, *Desh.*									*		*	*	*	*
Cardita australis, *Lamarck*								*			*	*	*	*
Venericardia media, *Hutton* (?)					*						*	*	*	*
Leda fastidiosa, *Adams*		*	*	*					*		*	*	*	*
Solenella australis, *Zittel*						*					*	*	*	*
Solenella funiculata, *Hutton*										*	*	*	*	*
Cucullæa worthingtoni, *Hutton*									*		*	*	*	*
Cucullæa attenuata, *Hutton*	*							*			*	*	*	*
Limopsis aurita, *Brocchi*								*			*	*	*	*
Limopsis insolita, *Zittel*						*					*	*	*	*
Pinna distans (?), *Hutton*	*										*	*	*	*
Pecten hochstetteri, *Zittel*	*	*		*					*		*	*	*	*
Pecten beethami, var. B, *Hutton*	*										*	*	*	*
Pecten venosus, *Hutton*	*										*	*	*	*
Pecten zittelli, *Hutton*			*	*							*	*	*	*
Placunanomia, sp.									*		*	*	*	*
Waldheimia lenticularis, *Desh.*	*								*		*	*	*	*
Waldheimia triangularis, *Hutton*					*						*	*	*	*
Rhynchonella nigricans, *Sowb.*									*		*	*	*	*
Amphidotus sulcatus, *Hutton*	*										*	*	*	*
Eupatagus grayi, *Hutton*			*								*	*	*	*
Brissiopsis alta, *Hutton*					*						*	*	*	*
Macropneustes spatangiformis, *Hutton*			*								*	*	*	*
Schizaster rotundatus, *Zittel*				*	*						*	*	*	*
Flabellum circulare, *Ten.-Woods*				*							*	*	*	*
Sphenotrochus huttonianus, *Ten.-Woods*			*								*	*	*	*
Graphularia senescens, *Tate*			*								*	*	*	*

Out of a total of 91 species noted above as having been recorded by Dr. Von Haast or Professor Hutton, 34 are noted only by the

former, and 29 are found only in lists by Professor Hutton, while 28 species are common to the lists of both.

The total number of species from the Oamaru formation, including therein the Waihao greensands, is 47; the number of species noted by Haast being 28, and by Hutton 26; while 8 only are common to the lists of both. Haast notes 19 species, and Hutton 20, that are not found in the lists of the other.

As belonging to the Pareroa formation, 53 species are recorded, and noted in the table above. Haast's lists contain 38 species and Hutton's 35, and there are 20 species common to the lists of both; 17 species in Haast's lists not being found in lists by Professor Hutton, and lists by the latter containing 16 species not given by Von Haast.

From the Waihao greensands—including with these the marly beds immediately under the Waihao limestones—there are noted 34. (I have excluded 3 species mentioned by Von Haast, considering them to be fossils of the Waihao limestones. These are *Pecten beethami*, var. B; *Pecten venosus*; *Amphidotus sulcatus*.) Haast's lists contain mention of 19 species, and Hutton's 23: there are thus 8 common to the lists of both; and 10 mentioned by Haast are not found in Hutton's lists, the latter noting 16 species not mentioned by Von Haast.

The species that are peculiar to the lists by Professor Hutton may be considered as additions to the fossil fauna of South Canterbury subsequent to the publication of "The Geology of Canterbury and Westland," but it is more difficult to account for the disappearance from later lists of the 34 species peculiar to the lists given by Dr. Von Haast. Many of these are species easily recognisable by marked peculiarities, are widely distributed, and so well known as leading fossils of the formations whence they come that there is no danger of their having been confounded with and noted as other species in the later lists. No species are mentioned in the lists of 1886 to which we might refer such forms as—*Fusus australis, Siphonalia dilatata* var. *(Fusus crawfordi), Mitra apicalis, Mitra enysi, Triton spengleri, Scalaria lyrata, Sigaretus subglobosus, Struthiolaria vermis, Trochita neozelanica, Crepidula striata, Turritella patagonica, Dentalium tenuis, Dentalium conicum, Venus stuchburyi, Cardita difficilis, Cardium spatiosum, Cucullæa worthingtoni, Cucullæa attenuata, Pinna distans, Pecten beethami* var. B, *Pecten venosus, Waldheimia lenticularis,* and *Rhynchonella nigricans:* hence the difficulty. The total number of species from the Waihao and Waitaki districts of South Canterbury noted in "The Geology of Canterbury and Westland" is, from the Oamaru formation 25, and from the Paeora formation 38, or a total of 63 species from the two formations here dealt with. The number of species forwarded to the Otago Museum in 1875 was about 68 (Trans. N.Z. Inst., Vol. IX., p. 594), of which 22 were new species, which Professor Hutton named and described the follow-

ing year; but, as 12 of these new species do not occur in South Canterbury (according to the lists of the time), this would reduce the original list of Waihao and Waitaki fossils to 56 species, or 7 less than the number mentioned by Von Haast; but, as Hutton refers none of the fossils of the Waitaki Valley to the Oamaru formation, and Haast refers 6 species none of which are mentioned by Hutton from any part of the district, there is thus but one species to account for in order to make the lists agree as respects the number of the species given by each; but there yet remain 27 or 28 species standing in the lists by Von Haast for which there seems no accounting. Twenty-three of these, of which a list is given above, are species respecting which neither Von Haast nor Professor Hutton could have erred as to their identity. What, then, has become of them, and why did they ever appear in the lists of Waihao and Waitaki fossils?

When we compare the lists of Pareora and Oamaru fossils from the Waihoa, Mount Harris, and the Waitaki, the result, whether as proving the Pareroa age of the Waihao greensands or the identity of the species cited at different times, is not more satisfactory. Dr. Von Haast gives as belonging to the Oamaru formation in the Waihao Valley in all 28 species of fossils, the beds yielding them being the Waihao limestone and the underlying greensands, and some beds in the Waitaki Valley. Professor Hutton's lists contain 26 species from the same beds. Combining the lists of both, there are 47 species altogether. The list given by Dr. Von Haast contains 19 species not appearing in Professor Hutton's lists, while the latter contain 20 species not appearing in the list by Dr. Von Haast: there are thus only 8 species in common. Admitting, as in the previous case, that Professor Hutton's lists contain a number of species collected since 1879, 13 of the species (or 19 less 6) from the Oamaru formation in the Waitaki Valley, in Dr. Von Haast's list, cannot be so accounted for. There is evidence that these 13 species were identified or named by Professor Hutton in 1876; but, at all events, "The Geology of Canterbury and Westland" is a work well known to him, and these 13 species ought not to have been overlooked when compiling his lists of the fossils of the greensands and the Waihao limestone. But this is not all: 3 species from these beds, unknown to Haast, and appearing only in Hutton's lists subsequent to 1879, although they were cited on the 31st March last,* are no longer to be found in the list of fossils from the Waihao greensands, and we are not made acquainted with the reason why they no longer appear.

It may be that *Trochita neozelanica, Crepidula striata, Pinna*

* Compare fossils of the "Waihao Forks" in "The Mollusca of the Pareroa and Oamaru systems," in Proceedings of Linnæan Society of New South Wales (31st March, 1886), with the list given in Trans. N.Z. Inst., Vol. XIX., p. 431.

distans, Pecten beethami var. B, *Pecten venosus,* and *Amphidotus sulcatus* were obtained by Dr. Von Haast from the limestone and calcareous greensand members of the Oamaru formation; but they widely differ from the fossils of the limestone as given by Professor Hutton, who, having access to the fossils of the district in the Canterbury Museum,* should have included them in his list or accounted for their absence. The lists of fossils from the Waihao greensand and the Waihao limestone have therefore a full share of that lack of correspondence which I have pointed out as affecting those of the combined Pareora and Oamaru formations. Nor are those of the fossils of the Pareora formation in greater accord. Out of a total of 53 there are 17 found only in the list given by Dr. Von Haast, 16 occur only in the lists by Professor Hutton, and 20, or less than one-half of the total number, are common to the lists of both; and, of the species not the same in the different lists, it is needless to say that their number cannot be reduced by supposing that different names are set down to what should be taken for the same species. This I have already shown.

Next we come to a consideration of the correspondence of the fossils referred to the greensands on the one hand and to the Pareora formation on the other; and in dealing thus with the lists of fossils at disposal, as Dr. Von Haast has not in every case discriminated between the fossils of the Waihao greensands and those from the overlying limestones, in order to make the comparison as just as possible I shall first have to compare his list with those given by Professor Hutton, and, after withdrawing from Haast's list what species I know or judge of as being fossils of the limestone, I can then compare them separately or together with the fossils of the admittedly Pareora beds of the same district.

Dr. Von Haast gives a list embracing 22 species as coming from the greensands and the limestones (?), or, at all events, from the Oamaru formation, in the Waihao Valley; and 23 have been referred to the Waihao greensands and the marls under the limestone by Professor Hutton. Of these latter, 16 are not found in the list by Dr. Von Haast, whose list likewise contains names of 10 species not found in the lists by Professor Hutton, and there is a correspondence of the names in the case of 8 species only out of a total of 37.

In the table above I have marked as fossils of the Waihao limestone only 3 of the species mentioned by Dr. Von Haast as coming from the Waihao and from beds belonging to the Oamaru formation; but, withdrawing the 6 I have mentioned as possibly being fossils of the limestone, there would then remain 31 species referable to the underlying beds, 7 of which would be found only in Haast's list, those peculiar to Hutton's lists being still 16, and there would be 8 common to the lists of both. While the 16

* Trans. N.Z. Inst. 1886, Vol. XIX., p. 430.

peculiar to Professor Hutton's lists may be supposed to have been collected since 1879, this cannot be said of the 7 that, occurring in Von Haast's list, are not mentioned by Hutton; and these should rightly have 2 more added, as, with good reason, *Ancillaria australis* is queried in the original list, and *Pleurotoma awamoaensis* is stated to be a variety only of Hutton's species.

On the other hand, *Peristerina cincta*, *Mitra inconspicua*, and *Cardium patulum* do not appear in Professor Hutton's latest list, and the total of species thus sinks to 28. These 28 are therefore the fossils of the Waihao greensand; for, though *Pecten zittelli* is claimed by Professor Hutton as a fossil of the Oamaru formation as distinguished from the Waihao greensands, it undoubtedly occurs in beds that overlie the greensands, as shown in the section at page 72 of the Geological Reports for 1881, this fossil occurring plentifully in Beds No. 5 of the section. But, excluding this and *Siphonotrochus huttonianus*, the lists of Haast and Hutton still contain 26 species which must be referred to the Waihao greensands. A list of these I give below.

FOSSILS OF THE WAIHAO GREENSANDS.

According to Haast.	*According to Hutton.*
1. Crocodilus, sp.	1. Crocodilus, sp.
	2. Aturia ziczac.
	3. Siphonalia nodosa.
4. Ancillaria australis (?).	4. Ancillaria australis.
5. Ancillaria hebera.	5. Ancillaria hebera.
6. Voluta elongata.	
	7. Voluta corrugata.
8. Mitra enysi.	
	9. Pleurotoma fusiformis.
10. Pleurotoma buchanani.	10. Pleurotoma buchanani.
11. Pleurotoma awamoaensis.	11. Pleurotoma awamoaensis.
	12. Clathurella hamiltoni.
13. Natica neozelanica.	
14. Natica suturalis.	14. Natica suturalis.
	15. Natica gibbosa.
	16. Natica hamiltoni.
17. Scalaria lyrata.	
18. Dentalium tenue.	
19. Dentalium conicum.	
	20. Dentalium mantelli.
21. Teredo heaphyi.	21. Teredo heaphyi.
22. Cucullæa attenuata.	
	23. Leda fastidiosa.
24. Pecten hochstetteri.	24. Pecten hochstetteri.
25. Waldheimia lenticularis.	
	26. Flabellum circulare.

The total number of species coming from the Pareora formation in the Waihao and Waitaki Valleys being 53, or 1 more than double the number of what have been collected from the greensands of the Waihao Forks, it might have been expected that most of the greensand fossils would occur in that collection; but not more than 6 out of 26 (the least number to which the

collection from the greensands can be reduced), or 23 per cent., are found in the Pareora beds. These six species are—*Voluta corrugata, Pleurotoma fusiformis, Pleurotoma awamoaensis, Dentalium mantelli, Leda fastidiosa,* and *Pecten hochstetteri.*

Voluta corrugata might occur in the Waihao greensands, but it is very significant that it is not mentioned by Von Haast; and Professor Hutton does not state that he added it to the collections in the Canterbury Museum.

Pleurotoma fusiformis also is not mentioned by Haast; and this is a very prominent species, respecting which no mistake could be made. I have collected largely from the Waihao greensands, but have not collected this species. I should also disallow *Dentalium mantelli,* for the reason that the Waihao specimens are not the same as the type figured by Zittel in the "Reise der 'Novara'" publications, and *Pecten hochstetteri* has such a range as to be valueless in this comparison.

But, however doubtful the identification of these species may be, admitting them all, they amount to but 23 per cent. of the whole collection. This is much less than the percentage of Pareora fossils found in the Oamaru formation. Professor Hutton gives a total of 84 species as having been found in the Oamaru formation, of which 51, or 60 per cent., are found in the Pareora system (Proc. Linn. Society of N.S.W., 1886, p. 215). The two systems are said to be unconformable to each other generally (*ib.*); and this unconformity is mentioned as being well marked in the Waihao Valley.

It is therefore perfectly manifest that palæontologically there is not a shadow of proof in support of the theory that would refer the Waihao greensands to the Pareora formation, and there is every proof that these greensands underlie the equivalents of the Ototara limestone, belonging to the Oamaru formation of Haast and Hutton, and to the Cretaceo-tertiary series of the Geological Survey. The stratigraphical evidence in favour of this conclusion is altogether beyond doubt, and, whatever the palæontological evidence may yet prove to be, I have shown that the material available is not such as warrants a decision at variance with what the stratigraphy proves; and Professor Hutton himself admits, "It is possible from a stratigraphical point of view that the greensands might pass under the marl of the Oamaru system" (Trans. N.Z. Inst., Vol. XIX., p. 432).

ON THE FOREST HILL COAL COMPANY'S COAL.

REPORT BY JAMES PARK.

Otapiri Gorge, Southland, 19th October, 1886.

I HAVE the honour to report that, in accordance with your instructions, I examined the coal on the property of the Forest Hill Company on the 18th instant.

The company's lease is situated on the rising ground at the lower slopes of the Hokonui Range, opposite the junction of the Makarewa and Otapiri rivers. The coal was first found on the low ground near the river, at a point only a few chains from the position indicated by you—as a likely place to find coal—on the sketch attached to your report on the mineral resources of this district, supplied to the Minister of Mines on the 4th December, 1885.

Since then the seam, the average thickness of which is about 10ft., has been proved by borings and shallow pits to be present throughout the whole of the lease, but, beyond getting out a few tons of coal for trial, nothing in the way of mining operations has yet been attempted.

AGE.

Like most of the other workable seams of coal in New Zealand, this coal belongs to the Cretaceo-tertiary period. It has been formed on an old land-surface of the Mataura rocks, from which it is separated by only a few feet of fine quartz-sands and fireclays.

The shallow prospecting-pits disclose very little as to the character of the rocks with which the coal is associated, but it is said to be overlain by a bed of fireclay, which, in turn, is followed by marly greensands which are well exposed in the banks of the Otapiri, a few miles to the north-west of this place. The Cretaceo-tertiary series is here closed by the Forest Hill limestone, which occupies the position of the Ototara stone of the classification.

EXTENT OF THE COAL.

The area held by the Forest Hill Coal Company is 200 acres, having a frontage of 50 chains to the Makarewa River.

The seam, which has already been proved in all the solid ground, varies in thickness from 9½ft. to 11½ft., and in estimating the amount of coal 10ft. may be taken as a fair average. Allowing 100 acres, or half the area, for the river-flats, where the coal is below water-level, and for the gullies where it has been removed by denudation, the remaining 100 acres, by the usual method of calculation—namely, 1,000 tons per acre for every foot of thickness—would contain 1,000,000 tons of coal.

The coal is well exposed in most of the prospecting-pits, and

appears to be very uniform in character, and free from foreign matter. It is moderately hard, and is said to stand the weather remarkably well; but of this I had no opportunity of judging for myself. It is said to be well adapted for steam purposes, the results of its trial on the Government railways being considered very satisfactory.

DEVELOPMENT.

The natural facilities for working this coal to advantage are very great.

In the first place, there will be no expense for drainage, as the seam rises gradually to the north, with sufficient fall to carry off the water; and in commencing mining operations there will be very little deadwork necessary, on account of the favourable position of the coal.

As to getting the coal to market, the facilities for transport are equally advantageous. The company's lease is within 90 chains of the terminus of the Government tramway from Winton, known as the "Gap Tramway," and, as the intervening country is almost level, there would be no difficulty in making the connection. It would be necessary to bridge the Makarewa, which however is narrow at this place, and confined within steep banks.

With a steady output there should be little difficulty in placing this coal in the market; and there can be no doubt the shareholders have acquired a valuable property, the development of which should add materially to the advancement of the district.

ON THE DISTRICT BETWEEN THE DART AND BIG BAY.

REPORT BY JAMES PARK.

Wellington, 9th January, 1887.

I HAVE the honour to inform you that, in accordance with your instructions to connect Mr. McKay's work at the Routeburn (Geological Reports, 1879–80, p. 118) with that of Mr. Macfarlane, from Jackson's Bay (Geological Reports, 1876–77, p. 27), I left Queenstown on the 6th November, and proceeded to Diamond Lake, where I remained till the 9th. The next day I crossed the Dart, and proceeded up the Rockburn by the blaze-track cut by Messrs. McBride and Robinson some twelve years ago. The track leaves the Dart about a mile above the junction of the Routeburn, and, passing the east side of Sylvan Lake, reaches the Rockburn about a mile from its mouth.

On account of long disuse, extending over ten years, the track is now almost impassable, and it was only by dint of hard work that the packhorses were got as far as the Rockburn the first day.

The next day I sent the packhorses back to Glenorchy, and with one field-hand proceeded up the gorge of the Rockburn and camped about three miles from the saddle. From the 12th to the 17th it rained almost incessantly, and, as the flooded condition of the river prevented further progress then, the time was occupied in bringing forward the camp and provisions to this point. On the 18th I proceeded over the saddle, and, descending to the Hidden Falls Stream, established a main camp about two miles from its source. The next day was spent examining the dunites and serpentines at the saddle which divides the Hidden Falls Stream from the Olivine. The next day I crossed this saddle, and, having followed down the Olivine about three miles, ascended the Bryneira Range, and, descending the west side, reached the north end of Lake Alabaster.

My route now lay along the valley of the Pyke; but, on account of the swampy nature of the ground, and the dense vegetation, which consists chiefly of white-pine and kiekie, with supplejack and bush-lawyers in great tangled masses, our progress was slow in the extreme, as each day's journey had to be cut in advance until the "Knoll" was reached. Beyond this I was able to ford the Pyke with ease; and on the 24th I arrived at the foot of the McKenzie Range, and the next day proceeded along the blaze-track from Grassy Flat to Big Bay. The two following days were spent in examining the rocks on the north side of the bay, and the beach-workings of the Big Bay prospectors.

On the 28th I again started inland. Having reached the Pyke by way of Grassy Flat, I proceeded to the Jerry Saddle, whence I crossed the north end of the Red Hills and descended to the Cascade River at the White Slip. I then followed the Cascade to its source, where it emerges from a large glacier; and from the south end of the Olivine Range worked on to the Barrier Range, which was traversed for several miles; but, on account of the uncertainty and danger of proceeding in the heavy mist which had enveloped the mountains for several days, I turned to the west and descended to the head of the Pyke River, which was followed to Grassy Flat, whence I again returned to Big Bay, which was reached on the 5th December. During this trip it rained six days, and, from the necessity of travelling every day, both in rain and snow, we suffered greatly from cold and exposure, more especially my field-hand, whose feet and knees got slightly frostbitten.

On the 6th I examined the coast between Big Bay and Martin's Bay, and the next day Webb's Gully, where alluvial digging has been carried on by the settlers of Martin's Bay for the past twelve or thirteen years. On this and the two following days it rained heavily, causing the highest flood of the Hollyford in the experience of the oldest settler at Martin's Bay. The next day, the 9th, which was the first bright day on the coast for several weeks, the Hollyford was 12ft. above its ordinary level, flooding all the low-

lying grounds in the valley, and threatening some of the settlers' houses. This was what the residents on the coast called "a mud-flood," as the waters, on subsiding, left a deposit of fine mud several inches thick over the flooded land, thus destroying much grass in the cleared paddocks, and cattle-feed in the bush. In Robertson's lower paddock the mud-deposit was over 2ft. deep, and so tenacious that the cattle stuck in it, and had to be assisted out.

A peculiar feature of this heavy rain was the extraordinary number of landslips which it brought down. On the 9th the bush-covered slopes of the Sarah and May Hills were observed to be scarred by large slips which had pushed trees, rocks, and every obstruction before them, in most cases exposing the bare rock beneath. One party of prospectors had a narrow escape from a slip, which swept past their camp, and at one time imperilled their lives. Webb's Creek rose 15ft. or 20ft. in a few hours, and carried away the only camp in the gully and all the mining tools. Fortunately enough there was nobody in the camp at the time, or loss of life might have resulted. On the 10th the Hollyford fell rapidly, and the next day I proceeded by boat to the head of Lake McKerrow, and thence walked to the "chair," which crosses the Pyke River a short distance below the south end of Lake Alabaster. The next day I crossed the Bryneira Range to the camp left near the source of the Hidden Falls Stream; and the succeeding day, by way of the Rockburn, reached the Dart, and thence the Routeburn Station.

On the 14th I proceeded to Glenorchy, and thence followed down the east side of Lake Wakatipu to the Twenty-five-mile Creek. The next day I examined the Cretaceo-tertiary rocks at Bob's Cove, on my way to Queenstown, which I reached the same evening. On the 16th I left for Wellington, where I arrived on the 19th.

PHYSICAL FEATURES.

The area examined during the progress of this survey is bounded on the east by the Dart, on the west by the Pacific Ocean, on the south by the Rockburn and Hollyford, and on the north by the McKenzie Range and Jerry River.

The whole of this region is of an excessively mountainous character, the mountains being steep and rugged, and in all cases bush-clad, while many of them rise above the line of perpetual snow, and maintain large snow-fields and glaciers throughout the year.

Between the Dart and the West Coast there are three almost parallel ranges, separated from each other by deep narrow valleys —namely, the Humboldt, Bryneira, and Skipper's Ranges.

The Humboldt Range, so called after the illustrious traveller of that name, extends from Lake Wakatipu to the Barrier Range.

It is by far the most important mountain-chain in this district, not only on account of its massive structure and the large area which it occupies, but also from the great height which it attains. Many of its peaks are between 7,000ft. and 7,500ft. high, and Mount Cosmos, near its northern end, is over 8,000ft. From this range the Dart receives three tributaries—the Routeburn, Rockburn, and Beanburn. The course of these rivers is short, in all cases under twenty miles, but they have cut deep narrow gorge-like valleys which extend almost right through the range, and terminate at low saddles, about 4,000ft. high, by which access can be had to the western watershed during the summer months. Both the latter rise from glaciers which lie on the mountains immediately to the north of their respective saddles.

The Bryneira Range, separated from the Humboldt Mountains by the Hidden Falls Stream and the Olivine, or Whitburn as it is sometimes called, is remarkable for its uniformity of outline and the equality of height exhibited by its higher peaks, many of which are over 6,000ft. and carry large fields of permanent snow. It extends from the Hollyford Valley to the Olivine Gorge, but the Red Hill Range to the north of this is merely a continuation of the same chain, being separated from it by only the narrow ravine of the above river.

The Skipper's Range, separated from that just described by the Pyke River, is the coast-range. It has a heavy massive appearance, and attains a considerable height, several of its peaks being over 6,000ft. high, while snow lies the whole year in many of its darker recesses and ravines. Both this and the Bryneira Range were named by Dr. Hector, who was the first to explore the Hollyford Valley, in the year 1863 (*Otago Provincial Government Gazette*, 5th November, 1863, p. 435).

The other mountain-ranges in this district are the Red Hill Range, Barrier and McKenzie Ranges, and the Red Hill. The former, which rises in some parts above 6,000ft., has already been described as a northerly extension of the Bryneira Range. A few miles north of the Olivine Gorge it is broken through by the Barrier River. On the range between these rivers rise two high snow-clad peaks, named Alexander Peak, 7,500ft., and Mount Beresford, 7,000ft. The sharp conical peak of the former is a very prominent object from the coast at Big Bay, but the latter, which stands more to the east, is only visible from the Bryneira Range or the Olivine Valley.

The Barrier Range, which throughout its length maintains a height between 6,000ft. and 7,000ft., is a northern extension of the Humboldt Mountains, connecting these with the Olivine and Redhill Ranges. It carries large fields of permanent snow and ice, and, from its precipitous, razor-back structure, is perhaps the most inaccessible of the mountain-ranges in this district.

The Red Hill, so called, forms one of the most prominent

landmarks on this part of the coast, and from its peculiar colour and great height is always an object of interest, even to those who only view it from a distance. It is situated about nine miles due east of Big Bay, and is bounded on the east by the Cascade River, on the north by the Jerry River, and on the south and west by the Pyke River and its tributaries. It forms a ridge about eight miles long and from two to four miles wide, the general trend of which is north-and-south; altogether it covers an area of perhaps thirty square miles. Its higher peaks attain a height of 6,600ft. above the sea; and in sheltered places it carries considerable fields of snow all the year. Except near the junction of the altered sedimentary rocks, it is entirely destitute of vegetation, its surface on all sides, from top to bottom, being one great talus of loose rocks, deeply furrowed by watercourses and snow-ruts. The striking dun-red colour of this ridge and its extreme sterility are mainly due to the mineral character of its rocks, which are chiefly dunite and serpentine. In extent, height, and ruggedness of outline the Red Hill rivals any of the secondary ranges of the coast, and a far more fitting and appropriate name would be "Red Mountain."

The McKenzie Range extends from Awarua Point to the Pyke, a distance of eight miles. It is bush-clad throughout its whole length, and reaches a height of 3,500ft. above the sea.

The low wooded spurs between Martin's Bay settlement and Big Bay are known as the May Hills. They are separated from the Skipper's Range by the Hokuri Valley.

Rivers.—The largest river on the eastern watershed is the Dart, which rises on the main range somewhere near the head of the west branch of the Matukituki; but its source has never been actually traced, and is still a matter of uncertainty. The only tributaries of any size which it receives are the Routeburn, Rockburn, and Beanburn, all of which rise in the Humboldt Mountains.

The next and perhaps most important river is the Hollyford, which, with its tributaries, the Pyke River and Hidden Falls Stream, drains almost the whole of the area forming the subject of this report. It drains the Darran Mountains, part of the Humboldt Mountains, and the Bryneira Range, the trend of its valley to the junction of the Pyke being almost north-and-south, and from there to the sea north-north-west. The Pyke drains the Red Mountain, Red Hill Range, and portions of the Barrier, Bryneira, and Humboldt Ranges. Between Grassy Flat and the Knoll this river approaches within five miles of Big Bay. South of this it enters a narrow gorge-like valley between the Bryneira and Skipper's Ranges, and, continuing its course south through Lakes Wilmott and Alabaster, falls into the Hollyford, little more than a mile below the latter. It is a large swift river, unfordable for man or beast for the greater part of its course.

The largest tributaries of the Pyke are the Olivine and Barrier, two considerable streams which break through the Red Hill and Bryneira Ranges, and join the main river between Lakes Wilmott and Alabaster.

Lakes.—The only lakes worth mention are Lakes McKerrow, Alabaster, and Wilmott. The former is situated near the mouth of the Hollyford, and is separated from the ocean by an alluvial flat less than three miles across. It is about 15ft. above sea-level, and is entirely fresh water, but it possesses all the characters of a fiord or sound, which it probably was at one time. It is by far the largest of the lakes enumerated above, being about nine miles long and two wide.

At two places the Pyke expands and occupies the whole width of its valley, thus forming Lakes Alabaster and Wilmott.

Lake Alabaster, which is the larger, is situated about two miles from the mouth of the river. It is about four miles long, and a mile wide at its widest part, which is the north end, from which it gradually tapers to a point at the south end.

Lake Wilmott is situated about eight miles farther up the river. It is about 130 chains long and 60 chains wide.

The formation of these lakes is probably due to the valley having become blocked by the accumulation of morainic matter, deposited by the great glacier which at one time filled the Pyke Valley.

Land for Settlement.—Under this head may be included the valleys of the Hollyford and Pyke and the low country between the McKenzie Range and Skipper's Range. The soil is a rich alluvial loam, at present maintaining a dense growth of forest vegetation.

Speaking of the Hollyford Valley in 1863, Dr. Hector says (*Otago Provincial Government Gazette*, 5th November, 1863, p. 437): "In some parts of the valley the flat land, which is of good quality and above the highest floods, is nearly two miles in width, and, as the soil appears principally to be a deposit from a lake that once extended from side to side, and probably occupied the whole of this valley and its ramifications, it will have a more uniform character than is usual in valleys so closely hemmed by mountains. The forest which covers the flats is very open and free from underwood, and contains some fine timber-trees, red-birch (*Fagus fusca*), ironwood (rata), rimu, and white-pine being the most prevalent. Above the second boulder-rapid, the rounded shingle, which lower down is confined to the bed of the principal stream and its tributaries, fills the valley from side to side, so that the useful land may be considered to terminate at that point, or about eighteen miles from the south extremity of the Kakapo Lake. It is extremely difficult to form any estimate of the extent of the available land in the valley, but I do not think it can exceed ten thousand acres. Its quality is, however, excellent, the soil

being generally a light friable loam, containing a proportion of vegetable matter."

Pastoral Land.—The lands available for pastoral purposes are necessarily limited to the mountain-tops; the valleys and lower slopes of the ranges, to a height of 3,500ft., being covered with forest. The Olivine, Barrier, and Humboldt Ranges are utterly worthless for grazing purposes, being mostly bare rock and snow above the bush-line. The Bryneira, Red Hill, and Skipper's Ranges are partially grassed, but in the absence of winter country it would be impossible to utilise them till the valleys are grassed.

Timber.—In the Dart Valley the only timber-tree of any consequence is the black-birch (*Fagus fusca*) of which some fine patches occur between the Routeburn and Rockburn, and around Diamond Lake. On the West Coast side, in the valleys of the Hollyford and Pyke, and along the foot of Skipper's and McKenzie Ranges, the principal timber-trees are black-birch, rimu, rata, and white-pine. Totara and matai are scarce, and generally of small size.

Gold. — As early as 1862 (*Otago Provincial Government Gazette,* 27th August, 1862), and again in 1878 (Geological Reports, 1878–79, p. 14), Dr. Hector pointed out that the great bulk of the gold of the western or lake district of Otago was derived from the soft mica-schists, belonging to the middle division of the foliated schists. On the Lake Wakatipu side of this district these softer schists occupy but a small area, being chiefly confined to the east side of the lake, and, excepting a small patch near Sylvan Lake, they do not cross to the west side of the Dart till the upper part of its course is reached; the Humboldt Mountains, and, in almost the same line, the Barrier Range and the north end of the Olivine Range, being formed of the more indurated rocks of the upper division of the foliated schists, which, while known to be auriferous, have not hitherto yielded payable results.

The auriferous rocks of the West Coast are subschistose, and possess mineral characters very distinct from those of the Lake District, just described. They are grey micaceous and siliceous sandstones, and dark-blue argillaceous slates, interbedded irregularly with soft grey or blue mica-schists, which often possess a peculiar wavy or finely-corrugated structure.

At Big Bay the rocks are grey micaceous sub-schists, weathering rusty-brown on the surface. They are interlaminated at intervals with quartz laminæ, and at first sight they resemble the foliated schists, but closer examination at the Sarah Hills and other places where they are better exposed soon proved the distinction, while their evident stratigraphical relations to the overlying Te Anau rocks showed that they belonged to the Kakanui series, which embraces the auriferous rocks of Naseby and Mount Ida, in Otago, and the Wakamarina and West Coast, Nelson. They

are pretty widely distributed in this district, forming the greater part of the McKenzie Range and Sarah Hills, part of Skipper's Range, and the lower slopes of the Bryneira Range, near Lake Wilmott.

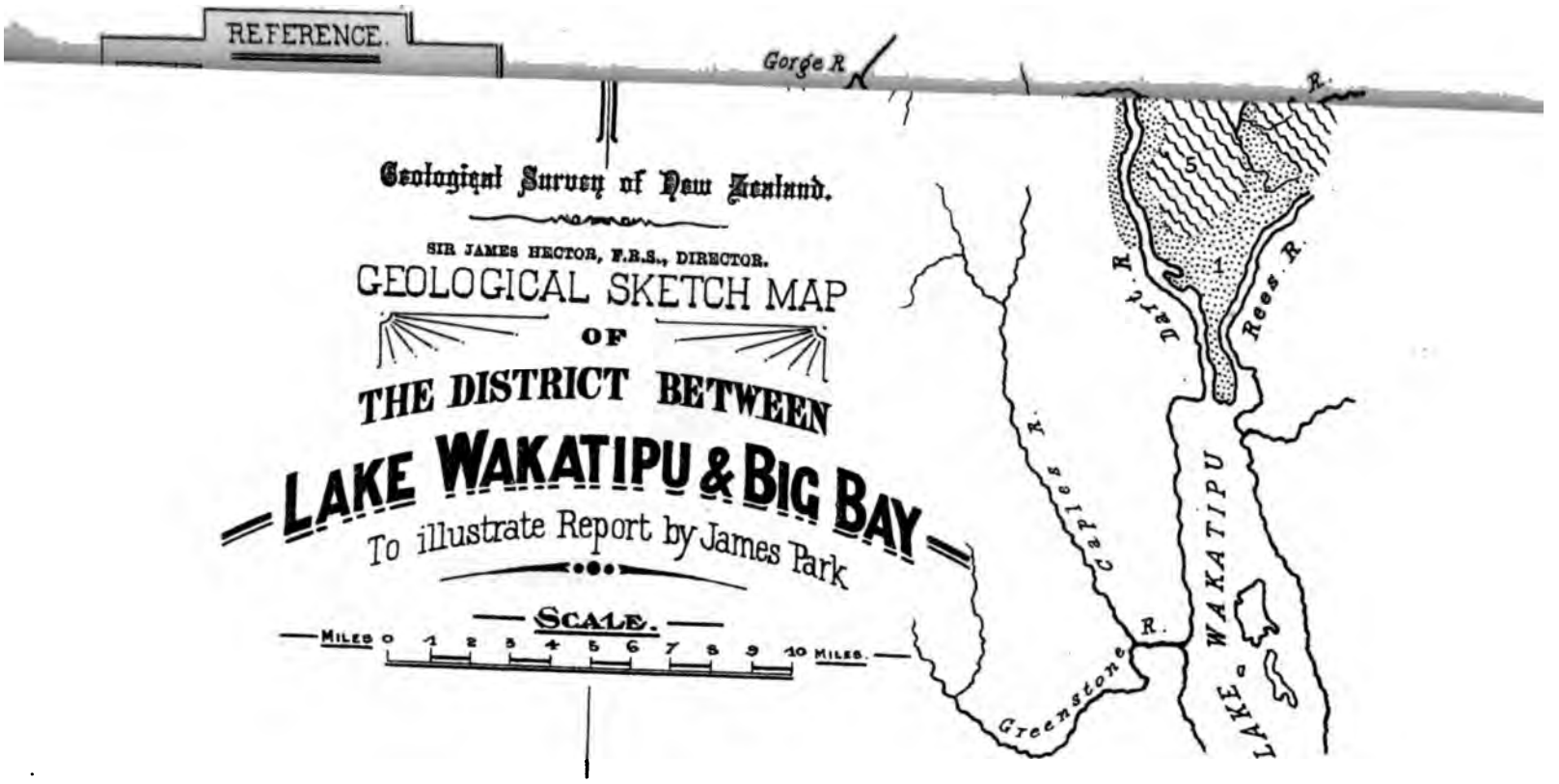
Gold has long been known to exist at almost every point of the coast from the Hope River to Milford Sound; but up to the present little inland prospecting has been attempted, Big Bay, Webb's Gully, and a few small beaches near Milford Sound being the only places that have received any attention from miners and prospectors.

At Big Bay the gold is found on the beach, which is occupied by numbers of large waterworn and angular boulders, derived from the high terraces which line the coast. During the past twelve or fifteen years many attempts have been made to work this beach, but they have not been attended with much success, principally owing to the exceptionally heavy nature of the work and the scarcity of water: however, I believe that, if this place were more accessible, admitting of greater facilities for procuring provisions, a large number of men might be induced to work out this ground, and thoroughly prospect the surrounding country.

At the time of my visit to Big Bay most of the remaining prospectors, sent to that place last November, were engaged "cradling" on the beach, but by this method of saving gold few of them were making more than 3s. a day, while the less experienced could not make as much in a week. The gold is coarse, but light; and it is generally admitted that there is still plenty of it to pay if a ready means of working the heavy wash could be devised.

Webb's Gully—or Pass Creek as it was first called, as it leads through the hills to Big Bay—drains the south-west spurs of the Sarah Hills, and falls into the Hollyford about a mile from the sea. Gold was first discovered here in 1873 by Messrs. Webb and Tarr, two Martin's Bay settlers, who worked out a rich prospectors' claim at that time. Since then a large amount of digging has been done in the gully, both by the settlers themselves and by others who have visited the coast. For the last year or two it has been much neglected, but several claims have now been pegged off by a few of the Big Bay prospectors. The creek is narrow and gorgy. It has a heavy fall, and the water, rushing between the large boulders of aphanite, aphanite breccia, and syenite, which occupy its bed, gives it rather the character of a mountain-torrent until it reaches the flat. The bare rock is exposed the whole length of the creek, the wash occurring in isolated patches sometimes on one side and sometimes on the other.

So far as I could see, all the easy and accessible ground has already been worked out, but sufficient still remains undisturbed to furnish employment for a limited number of men, who could undoubtedly make fair wages for a time. There is also a chance



Photolithographed at the General Survey Office, Wellington, N.Z. June 1887.

of some rich patches being struck. The dense bush which covers these hills, and in fact the whole country inland from the coast, is a great hindrance to successful prospecting, but still there is no reason why further research should not discover other gullies in this neighbourhood as rich as Webb's Gully in past times.

Speaking of the prospects of this as an auriferous country, Mr. Gerhard Mueller, Chief Surveyor of Westland, who made a topographical survey of this district during 1882–84, and included in his party several gold-diggers to prospect during his journeys, says (Surveyor-General's Annual Report, 1883–84): "A great part of the Hope Range is auriferous, and along the whole length of the Gorge River the colour is found on washing a dish of stuff. I believe that when once made accessible the Gorge country will prove a great field for hydraulic sluicing—the getting the necessary water-supply there will not be difficult. Almost all along the coast-line from Barn Bay to Martin's Bay the beaches and terraces carry gold. Some of these beaches proved very rich in the early days of the coast, and are still being worked. The colour of gold is also got in several of the tributaries at the head-waters of the Pyke River."

Other Minerals.—Attention was first called to the Red Hill country as likely to contain valuable minerals by the Red Hill Prospecting Company of Christchurch, which sent a well-equipped prospecting party there last year. After six months' work, of which three were spent in prospecting, they found nickel (awaruite) in small quantities, chrome, and traces of copper. These, however, were not considered sufficiently encouraging results, and nothing further was undertaken by this company.

During this survey I paid considerable attention to this subject. The Red Mountain was examined on all sides and crossed in two places, but the only metallic mineral I noticed worth mention was chrome, which occurs in considerable quantities on the Cascade side of the mountain. Among the non-metallic minerals were steatite and asbestos, neither of which appears to exist in sufficient quantity to be of economic value.

The Red Mountain is precisely similar in mineral character to the Dun Mountain, Nelson, and its chances of containing valuable minerals are not more favourable than at that place.

GEOLOGY.

The following is a table of the formations represented in this district:—

I. Recent—
  Alluvial flats, swamps, river-beds, glacier deposits, and high-level terraces.

VI. Cretaceo-tertiary—
  Shaly clays, greensands, conglomerates, and limestone.

XII. Carboniferous—
  a. Maitai series—Green, blue, and grey slates and grey limestone.

XIII. Upper Devonian—
a. Te Anau series—Aphanite sandstones and breccias.
b. Kakanui series—Grey micaceous sandstones, blue slates, and mica-schists, with quartz laminæ.
XVI. Foliated schists—
a. Upper—Green schists, mica-schists, with thin-bedded grey pyritous quartz.
b. Middle—Soft blue or grey mica-schists, interlaminated with quartz and green schists.
XVII. Crystalline schists. Grey pyritous rock.
Eruptive rocks—Dunites, serpentines, syenites, granites, &c.

I. Recent.

The alluvial deposits of this age are principally confined to the western part of the district, and occupy the Pyke Valley, the lower part of the Hollyford Valley, and the low swampy land between the higher part of the Pyke River and Big Bay. Glacier deposits are of small extent on this part of the West Coast, considering the amount of glaciation that has undoubtedly existed here in past times. A small area of low hills, composed of morainic matter, occurs on the west side of the Pyke River, near the Knoll; and except this I am not aware of any other accumulations worth mention. From this it may be inferred that the great glacier, which once descended from the Bryneira and Red Hill Ranges, most probably extended to the sea, there depositing its load of rocky *débris* in deep water.

The northern portion of the Bryneira Range is composed of a highly indurated grey pyritous rock, which has preserved the marks of former glaciation in a remarkable state of freshness. The average height of the range here is from 5,000ft. to 6,000ft., and it consists on its western side of a number of heavy square-shouldered spurs, separated by deep precipitous ravines. The spurs terminate abruptly, presenting steep faces to the Pyke Valley, thereby imparting a rather flat-topped appearance to the range, in a general view from a distance. They are mostly devoid of vegetation, and on examination are found to consist of great billowy rock-masses, with finely-rounded outlines, clearly showing the marks of long-continued ice erosion.

High-level Terraces.—The origin of the heavy terraces which fringe the coast from Barn Bay to Martin's Bay, at heights ranging from 100ft. to 300ft. above the sea, is a subject of great interest, and also of some importance, as affecting the distribution and origin of the gold on this part of the coast. The material composing them consists of a well-waterworn wash, mixed with a large number of rounded boulders of aphanite sandstone and breccias, dunite, and many varieties of syenitic rocks, a large number of which exceed 10ft. in diameter. They have long been known to contain gold, which has been shown, by means of prospecting shafts and drives, to be pretty evenly distributed throughout their entire mass, but not in sufficient quantities to be payable.

There can be little doubt, however, that the beach gold between Big Bay and Barn Bay is mainly, if not wholly, derived from these terraces, and the question arises as to the original source of the material composing them. On close examination the whole of the rocks are found to be foreign to the coast. All the large boulders, with the exception of the dunite, consist of rocks that belong to the Te Anau series, which does not occur *in sitû* nearer than the back ranges at the sources of the Pyke, Gorge, and Hope Rivers, where it is largely intruded by massive dykes of syenites. But the Awarua River does not extend back to this area, and is therefore incompetent to have brought down the material forming the terraces on the shores of Big Bay. This at once discloses the fact that this river must have at one time had its source at the Red Mountain; and this is obviously the case, as the large swampy flat which exists between the upper source of this river and the Pyke does not exceed 100ft. above the sea at the present time, and when standing on any elevated position the impression conveyed to the mind, judging from the general lie of the country, is that the Awarua still drains the Red Mountain area.

The gold found at Big Bay is all well waterworn, and ranges from fine to coarse, the latter predominating. This fact, together with its association with the characteristic rocks of the Te Anau series, seems to fully justify the assumption that it has been derived from the lower portion of this series, which, as already stated, is largely developed at the sources of the Pyke River.

VI. Cretaceo-tertiary.

These rocks occupy but a limited area in this district. They occur at two places only—namely, at the headlands which enclose Big Bay. They dip W. at very high angles, and are deeply involved in the old rocks. Their sequence, reading downwards, is,—

1. Coarse conglomerates and sandstones.
2. Hydraulic limestone interbedded with sandstone.
3. Gritty green and grey sandstones.
4. Slightly indurated marly clays with more calcareous layers, which weather out as ridges.

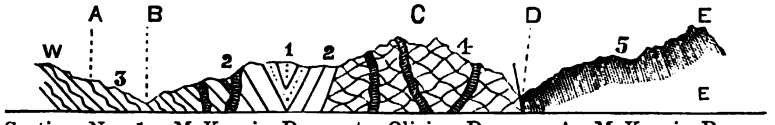
The conglomerates are principally composed of crystalline material, the bulk of which is syenite, which often occurs in large angular masses interbedded among the smaller and more rounded pebbles. Large blocks of hydraulic limestone are also included in the conglomerates, clearly showing that this bed was at least being partially subjected to denudation during the formation of the overlying coarser beds; but, so far as I could see, the strictest stratigraphical conformity appears to exist between all the parts of the series. Thin seams of bituminous coal are associated with the greensands, and in the grey sandstones occur indistinct plant-remains.

XII. Carboniferous.

a. Maitai series.

The rocks of this series are so closely related to the underlying Te Anau series that I had at first some doubts as to the propriety of distinguishing them as separate formations, and am now only induced to do so from the presence of a grey semicrystalline limestone in the section across the Bryneira Range, which has always been taken to be the base of the Maitai series.

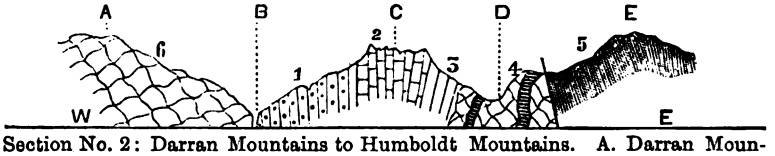
The limestone is not a constant member of the series. It thins out towards the north; and in the first section of these rocks which I examined, across the north end of the Red Mountain Ridge (line A–A on map), it is entirely absent. The sequence there is illustrated by the following section:—



Section No. 1: McKenzie Range to Olivine Range. A. McKenzie Range. B. Pyke River. C. Red Mountain. D. Cascade River. E. Olivine Range. 1. Maitai series. 2. Te Anau series. 3. Kakanui series. 4. Dunite and serpentine. 5. Foliated schists (upper).

In the above section the Maitai series is represented by Beds No. 1, which are grey, blue, pale-green, and red fissile slates. They strike N.–S., as do, in fact, all the formations in the district from the Cretaceo-tertiary to the foliated schists.

The relations of the slates to the Te Anau aphanites is very clearly seen on the bare rocky ridges leading up to the Red Mountain, and it was the very close stratigraphical connection which exists between them, and the absence of the limestone, that led me at first to include the whole of these beds in the Te Anau series.



Section No. 2: Darran Mountains to Humboldt Mountains. A. Darran Mountains. B. Hollyford Valley. C. Bryneira Range. D. Hidden Falls. E. Humboldt Mountains. 1. Maitai slates. 2. Grey limestone. 3. Aphanite sandstones and breccias. 4. Dunite and serpentine. 5. Foliated schists (upper). 6. Crystalline schists.

In the section across the Bryneira Range, along line B–B on map, the limestone is interposed between the fissile slates and the Te Anau aphanites. It cannot be less than 2,000ft., and throughout its whole thickness it is interbedded with thin layers of aphanite sandstone, which, as the dip is almost vertical, weather out and form innumerable narrow parallel ridges, which stand from 3in. to 6in. above the surface of limestone, and are traceable along the range for miles, forming one of the most remarkable

sights that could be imagined. Near its base the limestone is interbedded with heavy bands of aphanite sandstone. It strikes N.–S., and extends northwards along the western slopes of the range, gradually thinning out in this direction. Opposite the head of Lake Alabaster, where I first crossed the Bryneira Range, it has a considerable development, and still farther north it is moderately abundant in the shingle of the Olivine, which cuts through this range; but in the bed of the Barrier, several miles higher up the Pyke Valley, it is sparingly represented, while in the section across the Red Mountain it is entirely absent.

XIII. Upper Devonian.

a. Te Anau series.
b. Kakanui series.

a. *Te Anau Series.*—These rocks have a wide distribution in the central and western portions of this district. They occupy a large part of the Bryneira and Red Hill Ranges, and form the lower slopes of the Red Mountain. They are also present in the south-west corner of the Sarah Hills.

They consist of massive aphanite sandstones of all shades of green, and coarse aphanite breccias, which are characteristic of this series wherever it occurs. At the saddle at the head of the Hidden Falls Creek, and again at the Red Mountain, the breccias are in contact with the serpentines and dunites, while on the west side of the above saddle they lie on a highly-indurated grey pyritous rock, which has been doubtfully referred to the crystalline schists. Throughout the district they strike N.–S., and seldom dip at angles under 60°. The rocks of this series are everywhere intersected by massive dykes of red and grey syenites and granites, which however in no instance, so far as I am aware, reach the semi-crystalline limestone of the overlying Maitai series. They will be dealt with further on.

b. *Kakanui Series.*—The rocks included under this head are grey micaceous sandstones, dark-blue slates (which are frequently calcareous), and hard micaceous sub-schists interlaminated with quartz laminæ. Bands of soft mica-schist are associated with all these rocks, and impart to the sub-schists at Big Bay a strong resemblance to the auriferous rocks of the foliated schists, with which I at first included them.

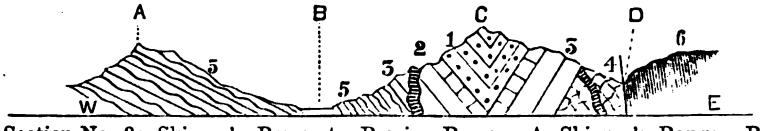
This series is principally developed in the McKenzie Range, Sarah Hills, Skipper's Range, and part of the Bryneira and Red Hill Ranges. At Big Bay and along the foot of the McKenzie Range they are hard micaceous sub-schists, with bands of softer mica-schist, which are interlaminated at irregular intervals with quartz laminæ. They strike N. 10° E., and dip E. at angles varying from 20° to 30°.

At the Sarah Hills, Skipper's Range, east end of McKenzie Range, and east side of Pyke Valley the rocks are hard grey

micaceous sandstones, blue calcareous schists, and soft mica-schists which possess a peculiar wavy or corrugated structure. At the Sarah Hills they are standing at very high angles and are much disturbed, and may be found striking in all directions in a small area, but their general strike appears to be about N.–S.

The relation of these rocks to the Te Anau series is not very clear at the Sarah Hills, where the low spurs are obscured by recent terraces; but the sections exposed on the slopes of the ranges on the east side of the Pyke Valley from the head of Lake Alabaster to Lake Wilmott leave little doubt as to their stratigraphical connection.

The section from Skipper's Range across the Pyke Valley to the Red Hill Range, along line C–C on map, is as follows:—



Section No. 3: Skipper's Range to Barrier Range. A. Skipper's Range. B. Lake Wilmott. C. Red Hill Range. D. North branch of Barrier River. 1. Maitai slates. 2. Grey limestone. 3. Aphanite sandstones and breccias (Te Anau series). 4. Dunites, serpentine, &c. 5. Micaceous sandstones, blue slates, and mica-schists (Kakanui series). 6. Foliated schists (upper).

The connection is also very clearly seen in the section from Big Bay to the Pyke, along the McKenzie Range. At the coast the micaceous subschistose rocks, interfoliated with quartz, dip E. at low angles, and are followed towards Grassy Flat by the grey micaceous sandstones and blue slates of the upper part of the Kakanui series (Beds No. 3, Section A–A), which are in turn followed by the aphanites of the Te Anau series.

XVI. Foliated Schists.

a. Upper division.
b. Middle division.

a. *Upper Division.*—These rocks occupy almost the whole of the eastern part of the district, embracing the Humboldt Mountains, the Barrier Range, and the southern end of the Olivine Range. They are green schists, quartzites, and grey pyritous quartz-schists, with softer mica-schists distributed throughout the series at irregular intervals. At different places, however, they present many varieties of mineral character.

At the Rockburn saddle the rocks are pale-green schists and quartzites, with bands of deep-green chlorite schist. These are overlain by a bluish-grey siliceous schist, which appears to be the highest member of the series.

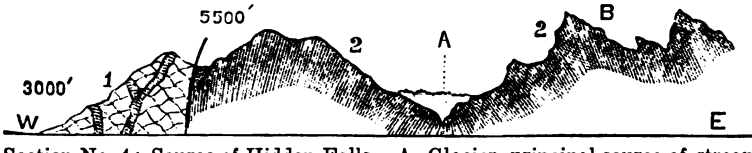
The whole series appear to have been subjected to great lateral pressure, and a fine example of this is seen about four miles above the bend in the Rockburn. The rocks here are alternations of very thin bands of green and blue micaceous schists, quartz laminæ, and green schists of every shade. The great pressure to

which they have been subjected has developed the most beautiful grainings and plications on surfaces sometimes only a few inches square.

On Mount Alfred the rocks of this division of the foliated schists are dark-blue micaceous schists, interlaminated at intervals with quartz laminæ, and intersected at intervals with innumerable quartz veins or strings. In dry places they weather a silvery-grey colour, and, on account of their extreme fineness, possess a striking silky lustre. In damp places they retain their dark-blue colour. They are generally thinly foliated, and split readily into slabs of any thickness or size, and for this reason are much sought after for flagging in the district. In their higher part, on Mount Alfred, they are interbedded with a greenish schist, with quartz veins, and are generally much twisted and gnarled.

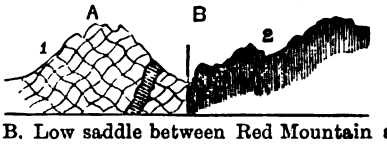
The rocks at the north end of the Olivine Range are blue mica-schists, with quartz laminæ, green schists, and quartzites. Close to their junction with the dunites and serpentines of the Red Mountain they are slightly talcose.

Throughout the district their strike is almost uniformly N.–S. At Mount Alfred and Mount Earnslaw, and on the east side of the Humboldt Mountains, they dip westerly at angles varying from 10° to 40°. On the west side of the Humboldt Mountains the dip suddenly changes, the beds now standing on end or dipping E. at very high angles. This high dip is continued along their whole extension from the high peak at the head of the right branch of the Routeburn to their northern limit on the Olivine Range. On their western boundary they are suddenly cut off by a fault, and at various places abut against the dunites and serpentines, the point of contact being an almost vertical wall. The following section illustrates an actual junction at the source of the Hidden Falls Stream, which was carefully examined for a height of 2,500ft. above the level of the saddle :—



Section No. 4: Source of Hidden Falls. A. Glacier, principal source of stream. B. Humboldt Mountains. 1. Dunite and serpentine. 2. Foliated schists (upper).

Another actual junction was examined at the south side of the Red Mountain, on the ridge between the Pyke and the Cascade :—



A. Red Mountain. B. Low saddle between Red Mountain and Cascade River. 1. Dunite and serpentine. 2. Foliated schists (upper division).

b. *Middle Division.*—The rocks of this division are soft blue and grey mica-schists, interfoliated with quartz laminæ, green schists, and quartzites. They are not stratigraphically distinct from the upper division, and it is frequently a matter of considerable difficulty to define their boundary with the overlying series. The distinction of their mineral characters is not very marked, the difference consisting principally in the more indurated nature of the rocks of the upper division, in which the soft mica-schists are not so largely developed as in the middle division.

In this district they occupy a narrow belt of low bush-covered hills between Sylvan Lake and the Dart, extending north to the Rockburn. The soft silvery-grey mica-schists with quartz laminæ, forming the eastern slopes of Mount Alfred and the western spur of Mount Earnslaw, should also be included in this division. At the former, overlooking Diamond Lake, there is an auriferous reef, which has been taken up by a party; and in the deep ravines in the flanks of Mount Earnslaw, opposite Paradise Flat, several specimens of schcelite have been picked up at different times.

XVII. Crystalline Schists.

These rocks occupy the northern portion of the Bryneira Range, extending from the source of the Hidden Falls to the Barrier River. They form the high peaks at the end of this range, overlooking the Olivine, and probably also Alexandra Peak and Mount Beresford; but I had no opportunity of determining this. They are highly indurated grey crystalline rocks with numerous quartz-veins. In some places they are very pyritous. Rocks belonging to this formation occupy the northern shores of Lake McKerrow, but, on account of the squally weather encountered on the lake, I was unable to land and examine them. Their extension there is copied from Dr. Hector's Geological Map of Otago, 1864.

Eruptive Rocks.

Dunite, Serpentine, Syenites, &c.—Excepting an inconsiderable patch at the source of the Hidden Falls Stream, only a few acres in extent, these rocks are confined to the northern portion of the district. Here they occupy part of the Red Hill Range, the whole of the Red Mountain and Gorge River Plateau, and the northern end of the Olivine Range. The rocks are principally dunite and serpentines, with which are associated nephrite or greenstone, hypersthene, bronzite, steatite, asbestos, chrysotile, picrolite, and chrome.

The dunite forms by far the greater mass of the Red Mountain and of all the areas occupied by these rocks, the serpentines occurring only as large vertical dykes, and the other minerals enumerated above as veins or reefs. The dunite weathers a dun-red colour, which imparts to these mineral areas a very characteristic red appearance. Large quantities of chrome are associated with the

dunite on the Cascade side of the Red Mountain, but whether as lodes or pockets could not be determined by a surface examination.

The serpentines are principally developed near the junction with the foliated schists. They are generally black or bottle-green. The new nickel-iron alloy (awaruite) found in the wash of the Gorge and Hope Rivers, both of which cut through the mineral belt in the upper part of their course, was traced to a serpentine matrix in which it occurs as dispersed grains (Colonial Museum and Laboratory Report, 1885–86, p. 49). The serpentines occur as dykes in the dunite, and are themselves intersected by numerous beautiful veins of chrysotile.

These magnesian rocks generally occur along a line of fault between the Te Anau series and the foliated schists. They do not form a continuous belt as in Nelson, but occur in isolated patches along this line, until they reach the Red Mountain, where they spread out and occupy a large block of country. At the saddle of the Olivine and Hidden Falls they come up between the crystalline and foliated schists.

Next in importance come the syenites and granites, which occur in great variety in this district. At first I thought they were associated with the dunite, but closer examination showed they were confined exclusively to the Te Anau rocks, through which they have been erupted as large dykes. Wherever this series is present it is found to be intersected by dykes of syenite or granite, which are, in fact, quite as characteristic of this series as the aphanite sandstones and breccias. These dykes are frequently several hundreds of feet wide, forming distinct spurs and ridges, and it is, no doubt, their massive character which has led to the belief generally prevailing among the miners and prospectors on the West Coast, that they are the fundamental rocks of the country. Fine examples of these dykes may be seen at the source of the Hidden Falls Creek, on the west side of the Pyke River, and in the Gorge and Jerry Rivers.

ON THE AGE OF THE WAIREKA TUFAS, QUARTZ-GRITS, AND COAL AT TEANERAKI AND NGAPARA, OAMARU.

REPORT BY JAMES PARK.

INSTRUCTIONS BY DR. HECTOR.

Wellington, 4th October, 1886.

I WISH you to examine the beds at Teaneraki, in the neighbourhood of Oamaru. These beds are probably the same as the Hampden (Onekakara) beds and the Waihao greensands, and should be traced

east till they pass under the Ototara limestone. From Teaneraki the beds will be found extending north-east between the south slopes of Big Hill and the scarp of limestone that stretches east from Teaneraki, and crosses Oamaru Creek at Devil's Bridge. It should be noted whether the greensands rest on the Waireka tufas, which at Teaneraki contain dykes or sheets of solid volcanic rocks.

Farther to the north, between Windsor and the forest tunnel, on the Livingstone line, are quartzose grits and sands. These are by Professor Hutton referred to the Pareora formation, Upper Miocene. They are probably the basement beds of the Cretaceo-tertiary series in the district, and should be traced south-west to the Kakanui River.

Mr. Esdaile should be consulted as to the locality of the large oysters mentioned in his last letter, as these are probably *Ostrea incurva*, the geological position of which is not known.

At Ngapara, see whether the coal there underlies the limestone.

JAMES HECTOR.

NARRATIVE.

Wellington, 30th June, 1887.

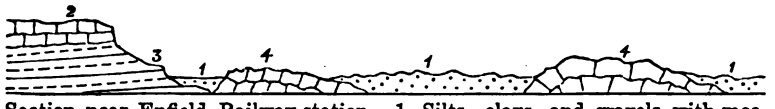
I HAVE the honour to inform you that, in accordance with the above instructions, I left Wellington on the 4th of October, arriving at Dunedin on the 6th. Next day I proceeded to Oamaru, and thence to Enfield (Teaneraki), where I was engaged till the 11th, when I returned to Dunedin.

REPORT.

OAMARU DISTRICT.

Instructions.—To trace the Teaneraki greensands till they pass under the Otatara stone, and to ascertain their relation to the Waireka tufas.

The Waireka tufas are largely developed in the Teaneraki district, and are well exposed in the fine escarpment sections on the east side of the railway-line, near Enfield. The top of the scarp is occupied by the Ototara stone, which is immediately underlain by yellowish-green tufas and tufaceous greensands. They are of marine origin; and about 50ft. below the Ototara stone I collected a number of fossils, the greater proportion of which are Terebratula. The others are Aturia, Pecten, Teredo, Cardium, and corals. These tufas and tufaceous greensands are from 200ft. to 300ft. thick, and at their base are exposed a number of bosses or dykes of volcanic rocks of a basic character.



Section near Enfield Railway-station. 1. Silts, clays, and gravels, with moa-bones. 2. Ototara stone. 3. Waireka tufas. 4. Volcanic dykes or bosses.

The Ototara stone can be traced almost continuously to Ngapara, where it rests conformably on greensands which contain a large number of fossils, including among them those found in the tufas at Enfield.

The greensands at Ngapara are only slightly tufaceous, while at Teaneraki the tufaceous matter predominates almost to the exclusion of the greensands. The Waireka tufas would thus appear to have been deposited towards the close of the greensand period, their tufaceous character at Teaneraki being due to local volcanic activity, which appears to have continued to the close of the Ototara stone, in the Oamaru district.

Instructions.—To ascertain the position of the quartzose sands and grits on the Livingstone line.

With this in view, I examined the railway-line between Windsor and the first tunnel, a distance of four miles. In the heavy cuttings along this line the quartzose grits and associated beds are well exposed, and, together with the fine natural sections here, afford great facilities for correctly determining the position of the grits.

The railway-line, on approaching the tunnel, passes up a narrow valley, in many places lined by high escarpments, capped by the Ototara stone. Taking the section at the east end of the tunnel to illustrate the sequence, the following rocks are seen:—

1. Ototara stone.
2. Grey glauconitic sands.
3. Greensands with fossils.
4. Fireclays and carbonaceous shales.
5. Fine white quartz glass-sands.
6. Loose quartzose sands and gravels, interbedded with hard flaggy ferruginous bands.

The quartz sands are interbedded with bands or layers of variegated clays. Both these and the quartzose sands and gravels are much false-bedded, and have a thickness of about 140ft. as seen in the railway-cuttings; but it may be much greater, as the sub-schists on which they rest at Ngapara are not exposed here.

The shales and lower part of the greensands are well exposed at the tunnel. The former contain numerous palm-nuts and other fruits; but, so far, no trace of coal has been found here.

On fresh surfaces, as in the tunnel and cuttings, the greensands are covered with a thin incrustation of sulphate of magnesia.

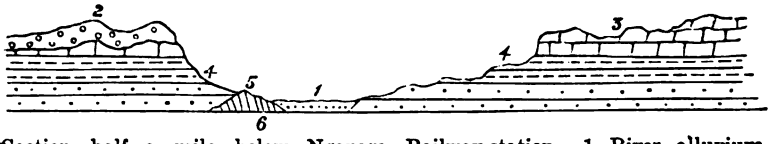
Mr. Esdaile, who accompanied me to this place, pointed out the railway-cuttings where he collected the large oyster, *Ostrea*

incurva, of which he has several specimens in his private collection at Enfield. The sands and clays in which it occurs are superficial slope-deposits, principally derived from the greensands; but there is still some uncertainty as to its exact horizon, as it could not be found *in situ*.

Instructions.—See whether the coal at Ngapara underlies the Ototara stone.

As this is a matter of considerable importance, I examined several miles of the escarpment sections near the Ngapara Railway-station, with a view of obtaining sufficient data to enable me to arrive at a reliable and definite conclusion. The sequence here corresponds closely with that described on the Livingstone line, and, as there, the beds dip to the eastward at a very low angle,—so low, in fact, that in short sections they appear to be horizontal.

A very fine section is seen at the railway-station, where the quartzose grits and sands, with a coal-seam which is being worked, are overlain by the greensands, which are in turn followed by the Ototara stone; but perhaps the most complete section is that exposed on the left bank of the stream half a mile below the station, where the grits are lying hard on the sub-schists :—



Section half a mile below Ngapara Railway-station. 1. River alluvium. 2. High-level river-gravels and clays, with moa-bones. 3. Ototara stone. 4. Greensands. 5. Quartzose grits with coal. 6. Arenaceous sub-schists.

2. *High-level River-gravels and Clays.*—On the north side of the Ngapara Stream these gravels rest on a highly-denuded surface of the Ototara stone. They consist principally of loose river-shingle, occasionally interbedded with finer sands and clays, in which I found several moa-bones in a good state of preservation. They are probably of Pleistocene age.

3. *Ototara Stone.*— At Ngapara this rock has lost all the characteristics of the fine Oamaru building-stone so well displayed a few miles to the eastward at Teaneraki. It is here more or less ferruginous in colour and much coarser in grain, being sometimes quite gritty or pebbly, especially near its upper surface. Besides Waldheimia, Scalaria, and Pecten it contains a large number of Kekenodon bones, fish-teeth, and several molluscs which are not found at the typical locality; while on the other hand the many beautiful corals and Foraminifera which almost entirely compose this rock near Oamaru are absent, a fact which is easily accounted for by the nearer approach to the old shore-line to the westward.

Standing on the high hills surrounding Ngapara, it is quite obvious that the Ototara stone at one time formed a continuous bed, gradually rising as a sloping plane from sea-level to an

altitude of several hundreds of feet on the flanks of the sub-schistose ranges to the westward, and extending far south into Otago, and north into Southern Canterbury, where in many places, as at the Waihao and Kakahu, it is as typically developed as at Enfield.

4. *Greensands.*—As at Enfield, the Ototara stone passes down into a grey sandstone, with numerous green glauconitic-like specks, which is seldom more than a few feet thick. It passes downward into the greensands, which are probably 300ft. thick here, and of many shades of colour and varying grades of texture. They are generally highly ferruginous, and about their middle part contain layers of decomposing ferruginous concretions, which enclose fossils in abundance.

5. *Quartzose Grits, with Coal.*—These rocks have already been described in the Windsor–Livingstone section. They occur in the same sequence as fine quartz-sands, quartzose grits with hard flaggy layers of red quartzose cement, and loose quartz-grits and fine gravels, lying hard on the sub-schists. Near their base the grits contain a seam of inferior brown coal, about 20ft. thick. The same seam can be traced eastward to Big Hill, where it has been worked for many years.

ON THE JURASSIC ROCKS OF THE HOKONUI HILLS, MATAURA, AND WAIKAWA.

REPORT BY JAMES PARK.

INSTRUCTIONS BY DR. HECTOR.

Wellington, 4th October, 1886.

I WISH you to make an examination of the south-east district of Otago, of sections from North Peak, Hokonui Range, south-eastwards to Waikawa, especially examining the Mataura River at the falls.

In the first place it will be as well for you to make a rapid examination of the section afforded by Otapiri Valley, which is fully described in the previous Geological Reports, as that will enable you to recognise the strata you will have to study, and to refer them to their proper position. It will also be advisable for you to examine the section along the old road from Popotuna to Mataura Falls; and also the coast-line from Waikawa to the mouth of the Mataura River.

The chief points in view are,—

1. To fix the relation of the Mataura Falls plant-beds to those at Otapiri, and also at Waikawa;

2. To ascertain the relation of the plant-bearing beds with silicified trees at South Head, Waikawa, to the conglomerates at the North Head, which contain *Tæniopteris stipulata;*

3. To ascertain the relation of the Mataura plant-sandstones to the Flag Hill series. JAMES HECTOR.

NARRATIVE.

Wellington, 30th July, 1887.

I HAVE the honour to report that I left Dunedin on the 13th October and proceeded to Invercargill, and on the 15th reached Otapiri Gorge. The following day was devoted to an examination of Astarte Hill and the low undulating ridges on the west side of the Lora Stream. On the 17th I examined the coal-outcrops on the lease of the Forest Hill Coal Company, situated on the lower slopes of the Hokonui Hills, opposite the junction of the Makarewa and Otapiri Rivers. On the 18th I examined the spurs on the east side of Coal Creek, and the vicinity of the old coal-workings there. The next two days were spent at Conical Hill, Flag Hill, and the bush spurs between Coal Creek and Forest Burn. On the 21st I examined the plant-beds at Mr. Rae's, on the Makarewa. The next day I proceeded through the Otapiri Gorge to the north side of Taylor's Creek, and thence worked on to the east end of Flag Hill Range, and after crossing the Lora followed the edge of the bush to the waterfall near the source of the east branch of that stream. The early part of the 23rd was spent in running the section to the north to connect with Mr. Cox's survey; and the remainder of this day and the whole of the 24th, in traversing West Peak, the Cap, Hedgehope, and the grassy spurs near Bushy Park.

On the 25th I examined the east and west banks of the Mataura River, from the falls downwards, about a mile; and the low hills that bound the flats on the east side. The beds at the falls were carefully examined, and a small collection of plants was made from the dark-blue shaly clays that follow the Bastion sandstones. The next day I proceeded along the old Popotuna road to Clinton; and on the 27th visited Landslip Hill, where I made a collection of fossil plants. The next day I proceeded to Fortrose, and thence followed the coast to Waipapa Point. On the 29th I examined the coast-line from Waipapa to Waikawa South Head, where a large collection of fossil plants was made. The 30th and 31st were spent in a study of the sections on the shores of Waikawa Harbour and at the North Head. On the 2nd of November I returned to Invercargill.

REPORT.

Making the Otapiri Gorge the base of my operations, I examined Astarte Hill and vicinity; Coal Creek; Conical Hill; the western slopes and ridge of Flag Hill, and the wooded spurs run-

ning from there to the Otapiri River; also the western slopes of the Hokonui Range as far south as the junction of the Makarewa and Otapiri Rivers. Also, starting from the Otapiri Gorge, I traversed West Peak, the Cap, Dunsdale, and Hedgehope, extending my examination of the Secondary rocks to Bushy Park on the eastern side of the Hokonuis, and thence to the Mataura Falls.

Coal Creek.—On account of the dense vegetation I was unable to find the site of the old drive, but, after spending some time in examining the rocks exposed in the bed of the stream, I picked up the shales and argillaceous sandstones which contain the coal-seams at this place, and from these beds I made a considerable collection of plants, most of which are well preserved and easily identified. The most common forms are *Pecopteris grandis* and another species something like *P. obtusata*, Asplenites, and Taxites.

The sequence of beds exposed in Coal Creek, from the top of the ridge on the south side to the bottom of the valley, is as follows, reading downwards :—

1. Coarse granite conglomerate.
2. Flaggy and concretionary brown sandstones.
3. Grey or green flaggy sandstone, with thin layer of crystalline conglomerate.
4. Argillaceous sandstones, with shales and thin seams of coal.

Bed No. 1 is a conglomerate principally composed of crystalline rocks, of which granites are the most common. It is well developed throughout the Hokonui area, and, having a thickness of from 40ft. to 60ft., forms an easily-recognisable horizon everywhere. For purposes of description it will be spoken of hereafter as the "upper granite conglomerate."

The flaggy and concretionary brown sandstones which immediately underlie the conglomerate are best seen at Astarte Hill, where they contain a bed of marine shells occurring as casts, the most abundant of which is an Astarte, which has given the name of "Astarte beds" to these sandstones. They vary a good deal in texture, and are often false-bedded with finer material, which contains broken plant-remains.

The Astarte beds are underlain by grey or green sandstones, which are mostly thick-bedded, and often exhibit a flaggy structure on weathered surfaces. In their upper part they are interbedded with a thin layer of conglomerate, about 2ft. thick, and throughout a considerable thickness contain dispersed pebbles and large indistinct plant-remains.

The lowest beds seen in the Coal Creek section are argillaceous sandstones of a blue or light-grey colour, which alternate with fine-grained grey sandstones full of plant-remains. These beds are about 150ft. thick. Towards their base they are interbedded with dark-blue shales, which contain thin seams of bituminous coal of very fine quality, varying from a few inches to 15in. in thickness. It was from these shales that the fossil plants from Coal Creek were obtained.

The dip here is S.S.E. at an angle of 10°, and, following the beds to the north, the fossiliferous shales were traced continuously to the eastern shoulder of Flag Hill, where they also contain distinct plant-remains, Pecopteris, Asplenites, Tæniopteris, and Taxites being collected there.

The greatest extension of Flag Hill trends almost at right angles to the strike of the rocks, and by continuing to the northward lower beds are seen than those exposed in Coal Creek.

At the base of the argillaceous sandstones and shales, with distinct plants and thin coal-seams, there is a thin bed of marine shells, of which the principal forms are Belemnites, Pecten, Modiola, Leda, Astarte, and Rhynchonella. At Conical Hill, in the Otapiri Gorge, this horizon also contains a small Spiriferina, and on this account has been known in previous reports as the "highest Spirifer bed" (Geological Reports, 1877–78, p. 61).

Still passing to the northward, the beds met with are, in descending order,—(*a*) thick bed of coarse grey sandstone with numerous large fragments of plants, and in places dispersed pebbles; (*b*) fine-grained blue sandstones with a thin bed of coarse grey sandstone (lower Belemnite bed of McKay: Geological Reports, 1877–78, p. 60), containing marine fossils, principally Belemnites, Pecten, Astarte (?), and Pholodomya (?); (*c*) coarse grey sandstone and shaly clays, underlain by a thin bed of grit, containing indistinct casts of Spiriferina, Pecten, Astarte, and Rhynchonella; (*d*) thin bed of gritty conglomerate; (*e*) shaly clays and coarse sandstone; (*f*) coarse crystalline conglomerate about 40ft. thick, composed principally of granites. This conglomerate forms well-marked features in this area, and will be called in this report "the lower granite conglomerate." The dip on Flag Hill is still S.S.E. at varying low angles that rarely exceed 15°.

Returning to the upper granite conglomerate on Flag Hill ridge, and proceeding southward, the following rocks are exposed in ascending order: (*a*) Banded shaly clays; (*b*) thick bed of coarse brown sandstone, passing up into a layer of conglomerate; (*c*) hard gritty greensandstone, with a concretionary structure on exposed surfaces, and a pebble-bed containing Belemnites, Ostrea, Avicula, Astarte, and Pholodomya; (*d*) concretionary marlstones and jointed sandstones with Inoceramus; (*e*) concretionary sandstone with plant-remains.

The total thickness of the beds between the upper and lower granite conglomerates is about 950ft., and of the beds above the upper granite conglomerate about 700ft.

Near the Lora the dip changes to N.N.E., the beds now forming a flat syncline, which runs from a point somewhere to the east of the Lora Gorge to the south-west extremity of the Hokonui Range, passing along the western flank of West Peak.

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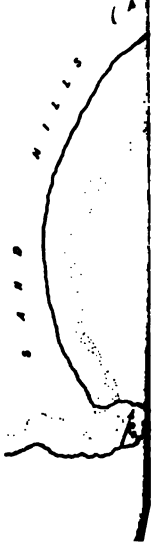


At McRae's farm, on the lower slopes of the Hokonuis, adjoining the Makarewa, the dip is S.S.W. at an angle of 10°. The rocks exposed here are,—

1. Coarse gritty sandstone.
2. Crystalline conglomerate.
3. Flaggy sandstone.
4. Argillaceous sandstone.
5. Argillaceous shales, with thin seams of coal.
6. Coarse brown sandstones.
7. Heavy crystalline conglomerate.

The argillaceous shales (No. 5) contain thin seams of coal, and numerous distinct fossil plants, of which a large number were collected, embracing *Pecopteris grandis*, Asplenites, Taxites, and two species of small Tæniopteris.

The brown sandstones contain large indistinct plant-remains and fragments of silicified wood.

The rocks of this section, as regards both sequence and lithological characters, agree closely with those at Flag Hill; the heavy granite conglomerates, Beds Nos. 2 and 7, correspond to the upper and lower granite conglomerates described there; while, of the intermediate beds, the argillaceous sandstones and shales at both places contain thin seams of coal and a flora that is almost identical.

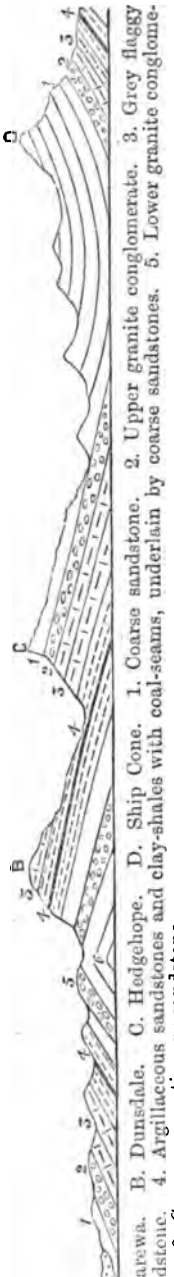
At the waterfall near the source of the left branch of the Lora, about two miles north of West Peak, the dip is N.N.E. at an angle of 10°, exposing the following rocks in descending order :—

1. Coarse brown sandstone.
2. Heavy granite conglomerate.
3. Grey sandstone, with large plant-impressions and dispersed pebbles.
4. Coarse greensandstones, alternating with layers of blue shaly sandstone.
5. Blue slaty shales, with distinct plants and coal-seams.

The greensandstones (No. 4) are well exposed in a high vertical cliff at the waterfall, where they consist of heavy beds of sandstone divided by beds of more shaly sandstone varying from a few inches to several feet in thickness, which on the tops of ridges and other exposed places weather a yellowish-white or grey colour, and assume a thin flaggy structure. They contain numerous plant-impressions, most of which are very indistinct, but *Pecopteris grandis*, Asplenites, and a small Tæniopteris can be distinguished.

The top of West Peak is occupied by the overlying grey sandstone (No. 3).

These beds were traced continuously along the strike from West Peak to the Cap; from there to Dunsdale and Hedgehope; and thence to Bushy Park, on the margin of the Mataura Downs. Plants were collected on the spurs near the Cap and at the foot of Hedgehope, where the blue slaty shales (No. 5) contain thin seams of coal.



A. Makarewa. B. Dunsdale. C. Hedgehope. D. Ship Cone. 1. Coarse sandstone. 2. Upper granite conglomerate. 3. Grey flaggy sandstone. 4. Argillaceous sandstones and clay-shales with coal-seams, underlain by coarse sandstones. 5. Lower granite conglomerate. 6. Coarse concretionary sandstone.

From the Lora to Bushy Park the strike is most regular and uniform; and from the latter place it continues direct for the Mataura Falls, situated about seven miles to the eastward.

The dip at all these places is N.N.E., the angle of inclination varying from 20° in the higher beds, as seen at Hedgehope, where 200ft. or 300ft. of coarse sandstones overlie the upper granite conglomerate, to 5° in the lower beds, which gradually flatten toward the south, forming a low anticline between Dunsdale and the Makarewa. North of Hedgehope the beds form a syncline, the sequence being repeated at Ship Cone, situated six miles to the northward, where the dip is S.S.W. at very high angles.

The section from the Makarewa to Ship Cone is represented by the accompanying sketch.

Farther to the east on the strike of the beds the same synclinal and anticlinal arrangement as shown in the section herewith is seen between Gore and the mouth of the Mataura River, a syncline with very high dips on its northern side occurring between Gore and the Wyndham River, and a low anticline between the latter place and the sea.

At Gore the dip is S.S.W. at very high angles, gradually flattening towards the centre of the syncline, which is situated about three miles above the Mataura Falls. From this point the dip changes to N.N.E., the beds rising at first at an angle of 20° or 25°, but rapidly flattening towards the south, so that at the falls their dip does not exceed 2½°, while a short distance below the Mataura Bridge they are lying almost horizontal.

About a mile and a half below the falls, on the east side of the river, brown sandstones are exposed close to the road, from which I collected Belemnites, Plicatula, Ostrea, Pecten, and Pholodomya. This sandstone is overlain by fine-grained argillaceous sandstones, passing up into dark-blue slaty shales, containing large plant-impressions and thin irregular seams of coaly matter. Near the base of the argillaceous sandstones, about 10ft. from the underlying marine bed, I obtained distinct plant-remains, including *Pecopteris grandis*, Asplenites, Taxites, and two species of small Tæniopteris.

Immediately below the bridge the slaty shales disappear below greensandstones, which alternate as heavy beds with dark-blue sandy shales, which are often only a few inches in thickness. These rocks continue to the falls, where they are interbedded with a band of crystalline conglomerate 2ft. thick, above which dispersed pebbles are common in the sandstone beds. Below the conglomerate, in the slaty shales, occur thin seams of coal and distinct plants, which, however, can only be got in small fragments, on account of the friable character of the shales. It was from the sandstones at the falls that Mr. McKay made his large collection of Macrotæniopteris in 1880, and the irregular patchy manner of their occurrence is well described in his report (Geological Reports, 1880-81, p. 41).

The sequence of rocks here is as follows :—

1. Coarse sandstone, with dispersed pebbles.
2. Band of crystalline conglomerate, 2ft. thick.
3. Greensandstone, alternating with thin layers of blue slaty shales with plants.
4. Argillaceous sandstones and dark-blue slaty shales, with plants and coaly matter.
5. Brown sandstone, with bed of marine shells.

The fossiliferous sandstone (No. 5) affords the means of determining the series to which these beds belong. The fossils clearly relate it to the highest marine horizon in the Flag Hill series of Cox, known as the lower belemnite bed; and, when a comparison is made of the beds overlying this horizon at Flag Hill and Mataura, they are found to be almost identical, both as regards their succession and their lithological characters.

CLASSIFICATION.

In his report on the Hokonui Hills in 1877 (Geological Reports, 1877–78, p. 36), Mr. Cox distinguished three distinct series above the lower granite conglomerate, which was placed as the highest member of the Bastion series. The Flag Hill and Putataka series included all the strata above the Bastion series as seen at Flag Hill, representing a total thickness of 1,650ft. The Mataura series, which was estimated to have a thickness of 3,500ft., consisted of certain rocks which were supposed to exist between Ship Cone and the Makarewa, including the plant-beds at the latter place. The existence of these beds was based on the assumption that the S.S.W. dip observed on the north side of Ship Cone was continuous to the Makarewa, where a southerly dip also prevails, thus giving a great thickness of strata superior to his Putataka series, and necessarily, according to this assumed dip, including the plant-beds at the Makarewa.

I have already shown in the preceding pages that the higher beds on the north side of Ship Cone form a syncline and an anticline before reaching the Makarewa. The plant-beds, with coal-seams, at Ship Cone, which form the higher part of the Flag Hill

series of Cox, are exposed by this arrangement of the strata at Hedgehope and the Makarewa, where a number of distinct plants were obtained. The same beds were traced from Coal Creek and Flag Hill to Hedgehope, and thence to Bushy Park, east of which they are obscured by the Recent and Tertiary deposits that occupy the Mataura Downs, until the Mataura River is reached, a distance of about seven miles. By protracting the strike eastward from Bushy Park the same beds should be found at the Mataura Falls, where, as I have already stated, the sequence of the beds is almost identical with that of the plant-beds at Coal Creek, Flag Hill, and Hedgehope.

Having shown that the area supposed by Mr. Cox to be occupied by the Mataura series is in reality occupied by his Flag Hill series, and that the Mataura Falls beds also belong to this series, the question arises as to the respective claims of Flag Hill and Mataura as a name for this series of beds.

During his survey of the Hokonuis in 1877 Mr. Cox applied the name Flag Hill to the high ridge between Taylor's Creek and the Otapiri River, the flag attached to the trig. signal on the summit having suggested the name to him. The ridge, however, is known to the settlers by another name, and, having no local significance, "Flag Hill" seems quite inappropriate as a name for an important series. The name "Mataura" was applied by Sir James Hector to the plant-beds at the well-known falls on that river, at the Township of Mataura, as early as 1862; and, as these form the most important and characteristic horizon of this series, I have adopted it in place of "Flag Hill."

The divisions proposed are as follow:—

VIII. Jurassic.—(*a.*) Mataura Series.

(1.) Lora Beds—
- *a.* Brown sandstones, with plants and carbonised wood.
- *b.* Marlstones with Inoceramus.
- *c.* Gritty greensandstone with bed of marine shells (Avicula bed).
- *d.* Coarse brown sandstone, passing up into layer of conglomerate.
- *e.* Banded shaly clays.
- *f.* Upper granite conglomerate.

(2.) Mataura Falls Beds—
- *a.* Coarse flaggy sandstones with dispersed pebbles.
- *b.* Layer of granite conglomerate, 2ft.
- *c.* Grey or green flaggy sandstone.
- *d.* Argillaceous sandstones and shales, with plants and thin coal-seams.

(3.) Flag Hill Beds—
- *a.* Brown sandstones with thin bed of marine shells (highest Spirifer bed).
- *b.* Coarse grey sandstone.
- *c.* Fine-grained blue sandstone, with coarse sandstone with marine shells (lower Belemnite bed).
- *d.* Coarse grey sandstones and shaly clays.
- *e.* Thin bed of grit with marine shells (little Spirifer grit).
- *f.* Shaly clays and coarse sandstone.
- *g.* Lower granite conglomerate.

In the above classification the upper and lower granite con-

glomerates, which form well-marked and easily recognisable horizons throughout the Hokonui area, have been placed at the base of the Lora and Flag Hill beds respectively. The latter includes about 1,000ft. and the former about 700ft. of strata, all of which are probably of estuarine origin, excepting, of course, the three marine horizons in the Flag Hill beds and two in the Lora beds, representing altogether less than 100ft. of strata.

The whence of the granites and other crystalline rocks in these conglomerates is a matter that cannot be determined with accuracy at present, in the absence of data relating to this point. That they are foreign to the Hokonuis is pretty certain, as no dykes or bosses of granites are known to exist in this area. The nearest granite occurs at the Bluff Hills and the Takitimu Range, both about twenty-five miles distant; and it was probably from one or other of these places, perhaps both, that these crystalline rocks were derived.

WAIKAWA.

Instructions.—(*a*) To examine the coast from the mouth of the Mataura to Waikawa; and (*b*) to ascertain the relation of the plant-bearing beds with silicified trees at South Head, Waikawa, to the conglomerates at the North Head, which contain *Tæniopteris stipulata.*

From the mouth of the Mataura to Waipapa Point, where the first rocky cliffs are seen, a large area is occupied by a belt of sandhills, inland of which there is a considerable tract of alluvial flat and swamp-land.

The rocks at Waipapa Point are coarse brown sandstones and pebbly conglomerates containing large indistinct plant-remains, and a quantity of silicified timber. In places they alternate with fine-grained argillaceous sandstones and blue shaly clays, which contain many fine plant-impressions. They are lying almost horizontal, and, as their strike is E.–W., they form the seacliffs the whole way to Waikawa South Head, where the sequence is as follows:—

1. Coarse pebbly sandstone, in places passing into a conglomerate.
2. Greensandstones, alternating with blue shaly clays with distinct plants.

Where not exposed to the action of the tide, the upper sandstones (No. 1) weather into small rusty-coloured concretions. The most characteristic feature of the underlying beds (No. 2) is the large quantity of silicified timber which occurs in them. Many stumps ranging from 1ft. to 6ft. in height, and in some cases as much as 2ft. in diameter at their base, are still standing in the places where they grew. On account of their more flinty and refractory nature they withstand the action of the sea much longer than the surrounding rocks; and it is not at all uncommon to see an erect trunk standing out in fine relief in the face of the steep sea-cliff, the massive root and smaller branching rootlets extending far into the underlying beds, and the trunk passing

upward through various layers or beds of sandstones and shales. As already stated, the rocks here are lying almost flat, and at low-water form low wide shelving ledges, which are thickly strewn with the fallen or prostrate trunks and limbs of these silicified trees, many of which are over 50ft. in length, while one was measured which exceeded 100ft.

In the upper part of the greenish sandstones (No. 2) very fine plant-remains occur in great abundance, the principal forms being *Macrotæniopteris lata* and *Tæniopteris stipulata*. A large number of other forms were also collected, including Pecopteris, Asplenites, Taxites, Lomarites, and Camptopteris.

The rocks at the North Head, commencing at the inside of the headland, are coarse crystalline conglomerates, which are underlain by alternating gritty sandstones and clay-shales, in which plants are common everywhere. A few feet below the conglomerates *Pecopteris grandis* is very abundant, and 150ft. below it the same form is associated with *Tæniopteris stipulata*. The beds here dip N. (magnetic) at angles varying from 45° to 75°. The conglomerate, which is about 90ft. thick, includes a number of large angular masses of granite, often from 3ft. to 4ft. in diameter.

The section from the North Head along the east side of the harbour to the saw-mill is as follows:—

A. North Head, Waikawa. 1. Sandhills. 2. Greenish sandstones, weathering red or rusty-brown, and interbedded with clay-shales containing coal-seams and distinct plants. 3. Coarse crystalline conglomerate, 90ft. 4. Brown gritty sandstones, alternating with indurated clay-shales with plants.

The beds Nos. 3 and 4 at the North Head have already been described, and require no further reference at present. Passing along the shore of the harbour the conglomerate (No. 3) is again met with, being repeated by a fault which has displaced the strata about 100ft. At the point where the sandy beach meets the cliffs it is overlain by heavy-bedded sandstones which weather a greenish-brown or rusty colour, and assume a concretionary structure in places where they are not subject to the action of the tide. They contain numerous plant-remains; but nothing distinct was found in them here, as they are so much obscured by the drifting sands that they present few advantages for careful examination. For the next mile or more the beach is occupied by low swampy flats and sandhills, which extend some distance back from the harbour. The only rock exposure in this distance is a narrow bush-covered rocky ridge, which extends down to the shore about 15 chains from the North Head. The south side of this ridge is occupied by the heavy conglomerate, below which a small part of the underlying sandstones is seen. The dip here is to S. at very high

angles, showing that the beds form a sharp syncline between this place and the North Head, where the dip is to N.

Beyond this no more rocks are seen till the point is rounded where the harbour widens, and its eastern shore trends to the north-east. The first rock exposed at the end of the line of low cliffs which bound the shores of Saw-mill Bay is the conglomerate, which, with the overlying sandstones (No. 2), dips to N. at angles varying from 10° to 35°. It thus appears that between the isolated rocky ridge previously mentioned and this point the beds form an anticline, which is flatter on its northern than on its southern side.

The upper sandstones (No. 2) occur in heavy beds, frequently divided by thin layers of clay-shale. They contain large nests of carbonised wood, thin coal-seams ranging from 4in. to 8in. in thickness, and in many places distinct plant-remains, principally Pecopteris and Tæniopteris. Proceeding northward the beds become horizontal, and north of Saw-mill Bay the sequence is repeated before the head of the harbour is reached. At the Quarry Reserve, where the upper greenish sandstones (No. 2) are at present being quarried, the dip is S.S.W. at an angle of 7°.

The synclinal and anticlinal arrangement of the strata, just described on the east side of the harbour, is also displayed on the west side, where the crystalline conglomerate forms at the different points of its occurrence well-marked features, that greatly facilitate the reading of the sequence. The beds corresponding to those at the North Head occur at the first creek, near the saw-mill, to the west of which the conglomerate forms a high rocky bush-covered ridge, considerably over 1,000ft. in height. The intervening space between this creek and the South Head, a distance of a mile and a half in a direct line, is occupied by heavy sandhills, which extend along the coast to Waipapa Point. They crown the sea-cliffs everywhere, and stretch inland several miles in many places.

The rocks at the South Head, although slightly faulted, have a northerly dip at an angle of 5°; but, on account of the obscurity caused by the sandhills, it is impossible to determine their relation to the conglomerate. If their dip is continuous to the saw-mill, then they are below the conglomerate; but, on the other hand, it is quite possible for the North Head beds to form an anticline in this space, and thus carry the Macrotæniopteris beds at the South Head above the conglomerate. However, I think this improbable, as the conglomerate, on account of its indurated character, always forms high rocky ridges wherever it occurs in other parts of the harbour, and if it existed anywhere in the area occupied by the sandhills it would probably do the same thing there: besides, the succession, character, and flora of the beds above the conglomerate are quite distinct from those at the South Head.

For the above reasons, and the strong resemblance of the lowest beds seen at the North Head to those at the South Head, I have placed the Macrotæniopteris beds below the conglomerate; but it must be admitted that the evidence to support this is rather of a negative than positive character.

The classification proposed for the rocks at Waikawa is as follows:—

I. *b.* Æolian series—
  a. Blown sands.
VIII. (*a.*) Mataura series—
  a. Waikawa Harbour beds.
  b. Macrotæniopteris beds, South Head.

I. Æolian Series.

The blown sands are confined to the west side of the harbour, where they occupy a narrow belt along the beach from the sawmill to South Head, whence they extend along the coast to Waipapa Point, and thence to the Bluff Harbour. They are everywhere auriferous, and have been extensively worked in former years, principally between Waikawa and Waipapa. The gold is perhaps the best in New Zealand, being worth £4 3s. per ounce at the Melbourne mint. It occurs as a very fine dust, which is difficult to save by the ordinary appliances usually employed in alluvial mining. It is pretty evenly distributed throughout the sandhills, and colours can be got almost anywhere. The sands contain a large proportion of black sand, which, together with the gold, is concentrated on the beach by the action of the tide. The method of working generally adopted by the few diggers now at Waikawa is to collect the black sand as the tide recedes, and paddock it above high-water mark. It is then put through long sluice-boxes which are filled with copper plates. The gold is afterwards separated from the black sand, which remains in the boxes with it, by amalgamation with quicksilver.

A more effective method of working these auriferous sands has recently been adopted by Mr. Brunton at Waipapa Point, who is now hydraulicking the sandhills with, I believe, very satisfactory results, as, on account of the large amount of material put through, a few grains of gold to the ton is found to be payable.

This mode of working has many advantages over the beach-workings, which can only be followed at suitable conditions of the tide; and, as the amount of material is practically unlimited, the mining industry of this coast has a very promising future before it.

The source of the gold is a matter of some uncertainty, as the auriferous schists and slates of Otago are not present on any part of this coast. The heavy crystalline conglomerate naturally suggests itself, and on crushing and washing a few pounds of it at Waipapa Point a number of fine colours were obtained: this, however, cannot be accepted as conclusive evidence of the presence

of gold in the matrix, as fine wind-blown specks may have been adhering to the interstices of the conglomerate; and experiments on a larger scale will have to be tried before this can be definitely decided.

Gold has also been found in the Mataura River, and in its tributaries near Gore, Mataura, and Tuturau, and at all these places the crystalline conglomerate is well developed, a fact which in a manner supports the view that the gold is derived from it.

VIII. Mataura Series.

a. *Waikawa Harbour Beds.*—The crystalline conglomerate, which is so well seen on both sides of the harbour, is supposed to be the horizontal equivalent of the upper granite conglomerate of the Hokonui Hills, described in the preceding report. It is mainly composed of crystalline rocks, of which granite is the most common. At the North Head it is interbedded with a number of large angular masses of granite, which have probably been deposited by the agency of floating ice.

These rocks are all foreign to this district, and were derived from an old land-surface that must have existed somewhere to the southward, and is now submerged, or only represented by Stewart Island and the small rocky islands between this and the main land. During Secondary times the area to the north of this old surface was occupied by a great sinking depression, in which several thousands of feet of strata were deposited, ranging from Triassic to Upper Jurassic.

The whole of these beds are of an estuarine character; at least no marine beds were observed during the course of my examinations here, but thin bands may occur, as at Flag Hill and Mataura, and have easily escaped notice on account of the outcrops of the rocks around Waikawa being obscured by a heavy forest vegetation. Thin coal-seams and broken plants are common enough in this series, but the number of distinct forms is very limited, the two most abundant being *Pecopteris hochstetteri* and *Tæniopteris stipulata*, both of which are well known in other parts of New Zealand.

b. *Macrotæniopteris Beds.*—The beds at the South Head, which were largely collected from by Mr. Buchanan in 1869, contain a flora almost identical with that found at the Mataura Falls. The two most characteristic species are *Pecopteris grandis* and *Macrotæniopteris lata*, which, so far as I can ascertain, have never been found above the upper conglomerate forming the base of the Lora beds.

The distribution of the rocks at Waikawa is shown in the sketch-map accompanying this report.

ON THE MARTON GOLD DISCOVERY.

REPORT BY JAMES PARK.

Wanganui, 18th January, 1887.

I HAVE the honour to report that, as instructed, I examined the locality of the recent gold-find at Marton on the 17th instant. The circumstances attending the discovery have already been fully reported in the daily papers, and are briefly as follow :—

In the beginning of December last Mr. J. Gomez began sinking a well on his lease near the White Hart Hotel. After sinking through 25ft. of heavy river-shingle and sand, a likely-looking black-sand wash was reached, from which a quartz pebble was picked with a number of fine specks of gold adhering to the cavities on its surface. As the sinking was continued frequent prospects were tried, with the result that a few colours of fine gold were found dispersed irregularly through the wash down to 40ft., at which depth sinking had to be discontinued on account of the influx of water. The best prospects were got at 25ft., and below that the wash yielded only a few colours to the dish.

Mr. Gomez informed me that his object in sinking the shaft was to drain his premises, and, this having been accomplished, he thought little more about the subject. He is an old alluvial digger himself, of seventeen years' experience, and did not consider the prospects sufficiently encouraging to undertake further prospecting.

So far as I can learn, the prospects do not average more than $\frac{1}{10}$th of a grain to the dish, which, as pointed out by Dr. Hector in his memorandum to the Minister for Public Works, would not be considered a rich prospect even if found on an open beach. In places where there is an unlimited quantity of auriferous wash and a good supply of water for hydraulicking purposes, a small return of gold, even as low as 3dwt. to the ton, is found to be payable; but in the case of deep leads the working expenses are very heavy, and it generally requires as many ounces to pay interest on the outlay.

The rocks at Marton are of Post-tertiary age, and lie unconformably on the younger Tertiaries of the Wanganui series. They are coarse river-gravels and sands, consisting principally of grey siliceous sandstones and occasional boulders of trachyte. The former are undoubtedly derived from the Kaimanawa Range, which is composed of similar rocks, and is drained by the Rangitikei on its eastern and southern slopes; while the volcanic material has been brought down by the Hautapu, which passes through an area of trachy-dolerite breccias and agglomerates between Ruanui and its junction with the Rangitikei.

The Palæozoic rocks of the Kaimanawa Range were proved by Dr. Hector to be auriferous as far back as 1866, and since then

prospecting parties have found small quantities of gold at the sources of the Moawhango and Rangitikei Rivers; it is therefore more than probable that the gold in the Marton gravels came originally from that place, and the black sand (magnetic iron) from the volcanic rocks of the Hautapu Valley.

Wherever the rocks underlying the drift of the Lower Rangitikei are exposed, they are found to be blue clays or calcareous beds belonging to the Wanganui series; consequently the probabilities of a slate or "reef" bottom are extremely remote; but even the drift itself is largely developed here, and I believe has never been bottomed, although a total depth of 380ft. was reached in one place by sinking and boring.

Taking into consideration the finely-divided condition of the gold and its sparing distribution throughout a great thickness of wash, I do not think it would be advisable to expend more money here in prospecting work at present. If coarse gold exists at all, it will be found somewhere nearer the back range, since the gold here, being fine and light, would necessarily be carried farther than the heavy gold.

ON THE GOLD DISCOVERY AT WAIMARINO.

REPORT BY JAMES PARK.

Pipiriki, 29th January, 1887.

I HAVE the honour to report that, as instructed by your memorandum of the 14th instant, I proceeded to Waimarino and examined the localities of the reported gold discoveries at that place on the 26th instant.

About fifteen months ago one of Mr. Rochfort's survey labourers named H. Nicoll, who has had some experience as an alluvial miner, prospected the Waimarino and a small stream that falls into this river half a mile below the Maori pa. The best prospects were got on the right bank of the Waimarino a few chains from the pa, where four fine "colours" were raised in one dish, while at the small stream just mentioned the prospect never yielded more than two colours.

Accompanied by Nicholl I carefully examined both places, and at the former washed a quantity of dirt, but failed to get even a colour. The sands and gravels which form the banks of the river, and, in fact, the whole of the terraces of the Waimarino Plains, are composed entirely of volcanic rocks which have been derived from Ruapehu and Hauhungatahi, both of which are partially drained by the Waimarino and its tributaries.

When first informed of the discovery of gold here I concluded that an outcrop of the Palæozoic rocks of the Kaimanawa Range had been found in some of the deep ravines leading up to Ruapehu. But this is not the case, and a close inspection of the rocks in the

terraces and streams in the neighbourhood could not discover a trace of slate, sandstone, or quartz.

A few chains below the prospecting-holes on the Waimarino there is a small outcrop of a soft, yellow micaceous sandstone belonging to the Wanganui series. In the Manganui-a-te-ao this rock is underlain by a pebbly cement-bed composed of quartz and sandstone, and it is probably from this cement, now obscured by volcanic *débris*, that the gold has been derived: that is, it occurs as a rewash from the cement; and, considering the great thickness of material in which it is distributed, I do not think there is anything to warrant the assumption that payable gold exists here.

ON THE MOKIHINUI COALFIELD.

REPORT BY DR. HECTOR.

[With Two Plans.]

Wellington, 7th January, 1887.

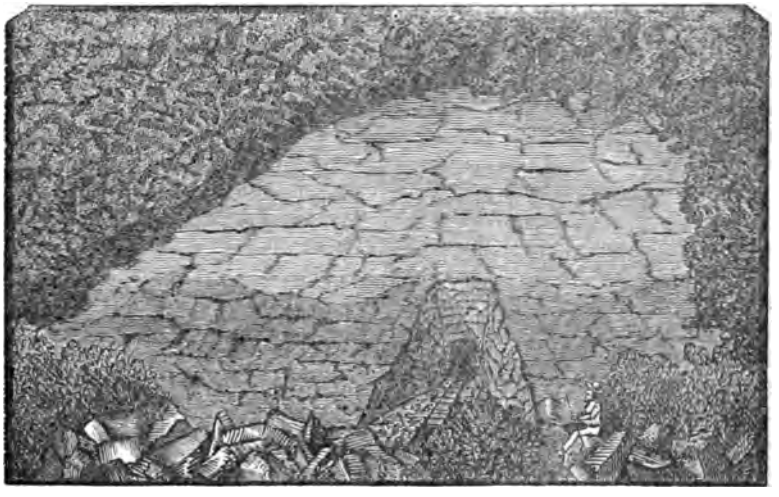
THIS important extension of the Buller coalfield was examined by Mr. McKay in August, and by myself in December last. Coal-seams were known and worked in an imperfect manner at Page's Creek within four miles of the mouth of the Mokihinui River as early as 1864, under the direction of the late Mr. Burnett, M.E. These workings were again opened by the present company, and communication effected by the construction of a short railway; but the seams have proved to be so broken that the coal could not be profitably worked.

Reserving this part of the field for future operations, the attention of the company has lately been directed to opening up coal-seams which I first discovered in 1866 farther inland, on a tributary called the Parenga, and now known as Coal Creek.

As Mr. McKay's report, which follows this, describes the general extent of the coal formation at Mokihinui, and the evidence of the occurrence of workable seams in different parts of it, I will confine my observations to the particular district where prospecting operations have been carried on, with the view of exploring the western part of the coal-basin intersected by Parenga Creek.

Nine outcrops of coal were here examined, two of which had been explored by short drives, the remainder being merely surface scarps in the positions shown upon a plan which I made on the scale of 5 chains to the inch. The coal formation consists at the base of coarse conglomerates, passing into quartz-grits. These are followed by a shaly formation, containing the coal-seams; and this is again covered by a thick formation of brown clay-shale. It is supposed by some that the middle group at this place carries two distinct coal-seams—upper and lower: first, on account of

the difference in quality of the coal, and secondly on account of a supposed difference in the thickness of the seams within a short horizontal distance; but on these points I could not satisfy myself, and for the present I am rather inclined to think that there is only one seam within the intermediate area referred to. The bed of Coal Creek follows very nearly the average water-level of the coal on the line that separates the roof of the coal from the overlying shales; so that, in general terms, all the coal lying on the north-east side of the creek is deep coal, while the coal on the south-west side will be obtainable by level-free workings. The greatest observed thickness of the seam is where a face is exposed on the south bank of the river, showing 32ft. in thickness of pure hard solid coal of excellent quality. This remarkable natural outcrop of coal presents the appearance in the accompanying sketch.



At none of the other outcrops is the full thickness of the seam exposed, and estimates that have been suggested, varying from 10ft. to 6ft., are quite unreliable, and require verification by opening into the coal so as to expose both the floor and the roof, where there is a good solid covering free from surface-slips; or, still better, by putting down bores at well-selected points, which latter course would also settle the important question as to whether there is more than one distinct seam in the property. There is evidence of only one important dislocation of strata—at the point marked E, where there is an east-and-west fault with a down-throw to the south, which brings the brown-shale formation for a distance of 10 chains on to the south-west side of the creek; and this throwing-back of the coal more deeply under the solid ground in that direction is, if anything, a favourable feature for facilitating mining operations. The amount of throw of this fault cannot be

ascertained until it has been exposed by either driving or sinking; but it does not probably exceed 60ft. or 70ft.

Owing to the denudation by the creek, the outcrop of coal follows a line on the south side of the creek irregular both in altitude and direction. The rise of the coal to S.W. is about 1 in 12, while the rise of the slope of the hill is about 1 in 5, so that in a short distance the coal-seams gain a very fair and solid covering, although possibly not sufficient to allow of a 30ft. seam being completely excavated.

Extent of Coal.—As only one fault, and that having an east-and-west direction, has been observed in a distance of 20 chains, the coal may be reasonably expected to occur throughout the high ground lying between Coal Creek and Page's Creek, where it has also been found to crop out. Making a rough estimate of the area denuded by the action of the creeks, and taking only the more solid parts of the country, it may be put down as only half a square mile, which is very moderate. The actual measurement is a strip north-east and south-west, 70 chains in length, and varying in width from 50 chains at the south to 40 chains at the north end. Assuming the seam to average 3 yards—which is well within the mark—the amount of coal available in this area alone exceeds three million tons. The character of the coal, the nature of the roof and floor and of the associated strata, being precisely the same as that on the Mount Rochfort plateau and at the Upper Ngakawau, I have no doubt that the coal formation is the same as at those places, and will probably be continued with only local interruptions, in which case the mine opened in this locality will be only the first of a series that will deliver towards the outlet of the Mokihinui River.

With reference to the 32ft.-coal, it is quite possible that this may prove to be a local expansion of a seam that is elsewhere of moderate thickness, as similar expansions over extremely limited areas are not infrequent in other parts of the field. But it would have an extent of many acres, and, from the position in which it occurs, I think it would be more economically worked by an open face like a stone quarry, stripping the surface-cover until the working face became too high for safety. As each acre of a 30ft. seam contains over thirty thousand tons of coal, and the surface of the ground slopes back at only a slightly steeper angle than the roof of the seam, and as the whole of this coal could be removed by the open-face system of working, a very large quantity could at once be obtained by this method at small expense.

Quality of the Coal.—In addition to a previous analysis which has been already reported, fresh samples were analysed, as shown in the following table, in which are incorporated all results from these beds. Most of the coals cake strongly, and are of excellent quality both for household and steam puprposes. The coal taken from the middle of the 30ft. seam proved to be one of the best

steam-generating coals that have been found in New Zealand, as will be seen from the tabulated evaporative power. The coal from the supposed 10ft. seam, opened out at F, is, perhaps, of all, the best suited for household purposes :—

Seam.	Fixed Carbon.	Hydro-carbon.	Water.	Ash.	Evap. Power.
Outcrop opposite to hut	53·91	39·72	5·16	1·21	7·0
Tunnel-face opposite to hut ..	58·34	32·38	8·51	·77	7·6
Tunnel-face in 30ft. seam, Big Face	64·32	27·70	6·01	1·97	8·3
Middle of outcrop	60·02	29·35	9·61	1·02	7·8
Outcrop 10 chains south of Big Face	59·02	31·60	8·57	·81	7·6
Outcrop 5 chains south of Big Face	57·76	32·84	7·01	2·39	7·5
Coal from seam in fault	59·42	33·33	6·24	1·01	7·7

NOTE.—The ash is white or light-buff, and does not form a hard clinker.

It appears from these analyses, therefore, that the coal from every point of the area examined is practically of the same quality, the variation in composition being quite within the ordinary limits from different parts of the seam in other places, and the best quality of all is possessed by the coal taken from the drive which has been made into the Big Face of the 30ft. seam.

Suggestions.—The prospects disclosed as above are, I consider, most encouraging, and prove that the great Buller coalfield, owing to the general northerly dip of the formation, reaches the sea-level in the vicinity of the Mokihinui Valley, which thus affords unusual facilities of access to the coal-deposits. The coal-basin is here about three miles in width, and hitherto the only attempted workings have been on the western side in the lower part of Page's Creek, and these have not been very successful as yet. The difficulties encountered at these places arose however from the existence of a series of close parallel faults that have been caused during the excavation of the gorge of the river, and which are very similar to the faults that have complicated the working of coal at the Grey River Gorge.

There is no doubt that, when better explored and surveyed, even this part of the basin will be successfully worked; but the difficulties here encountered do not appear to exist at Coal Creek, so that, although it involves longer carriage of the coal for a few miles, and necessitates the extension of the present railway-line, I think it would be quite justifiable to suspend the Page's Creek workings for a time, and to open those at Coal Creek. The difficulties in the way of carrying out the extension of the line are not great, and are chiefly at the crossing of Page's Creek, and in the upper part of the valley of Coal Creek; but it so happens that at both of these places the necessary excavations will be of great

service in exploring the coal-measures, and may lead to important results in that way.

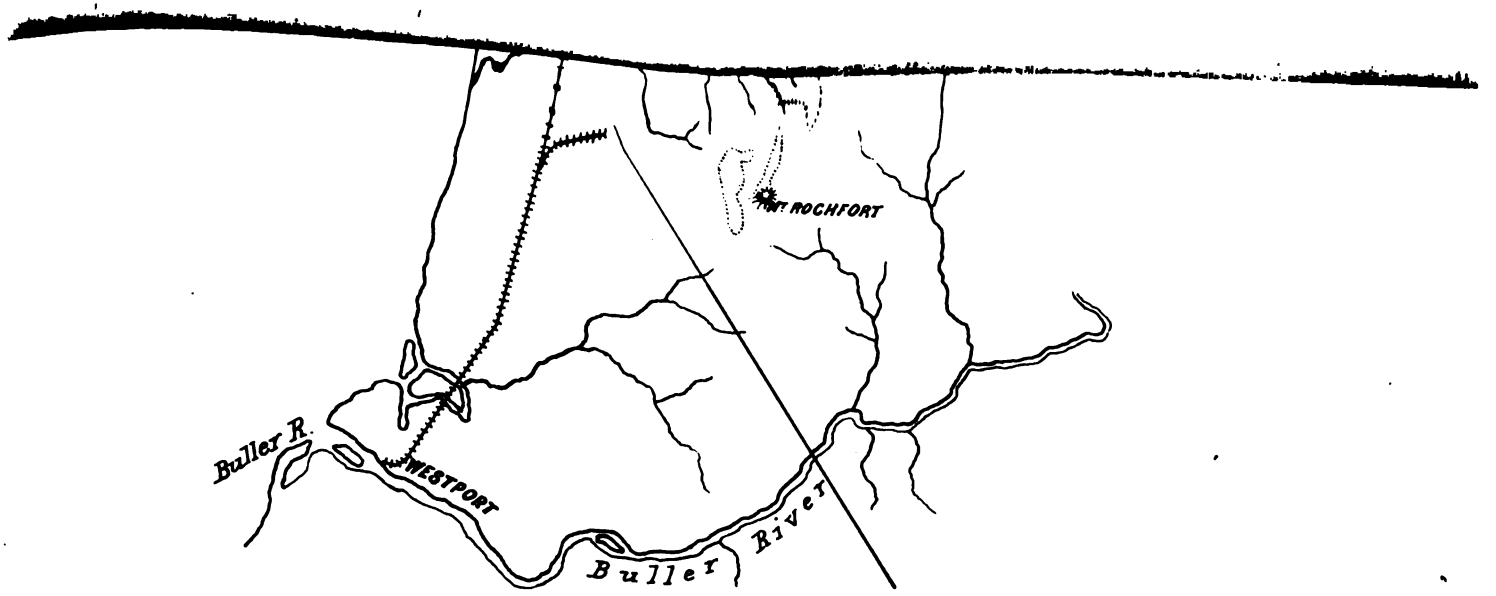
While the access is being provided, the most important work will be that of laying out the exact form of mine-workings to be adopted. The open working of the Big Face requires very little preliminary work, and the excavation of the coal need not be commenced until rails are laid to take it away. The bush, however, may be felled and cleared, and the surface-ground prepared for stripping. This could be most economically done by hydraulicking with a head of water, and the same water-supply could be applied for water-screening the coal, which would add greatly to its value. If the head obtained were sufficient it could also serve for working coal-cutters, and lifts to put the bottom coal on the screens, as the adoption of such modern appliances would all tend to increase the profits. A pressing preliminary work is the thorough exploration of the fault in Section E, and for this purpose a drive should be put in a little above the creek-level on a south-west bearing. If the coal is thus cut on the level beyond and on the down-throw side of the fault, it may be possible to lay out the approach to the Big Face D, by tunnelling through coal for the whole distance above the fault, and so avoiding expensive deadwork on the rocky sides of the gorge.

The seam opposite the hut should also be more thoroughly opened up, and its correct thickness from floor to roof ascertained. This should also be done by driving and sinking at the outcrops in Sections A and C, and a few bore-holes should be put down on the plateau towards Page's Creek, so as to determine the extension of the coal in that direction. The outcrop of the coal above the fall, on the small tributary creek below the hut, should also be searched for, and traced, if possible, to the bluff on the river-bend at K, which would be a favourable position from which to work the level-free coal on the uprise side of the fault. I do not suggest these further explorations on account of their being necessary to insure the good prospects already disclosed, but rather to enable the exact scale of expenditure for the future to be placed on a definite and solid basis of observed fact.

NOTE.—Since the above was written, a bore-hole has been put down through the floor of the 32ft. seam, at the end of a drive that has been made into the face. The following beds were intersected under the coal: Clay, 1½ft.; coal, 3ft.; grit, 18ft.; coal, 7½ft.; clay. This proves that there are two distinct seams of coal, and that the seam opposite the hut underlies the Great Seam. This result greatly improves the prospects of the coalfield.

June, 1887. J.H.

SECTION AA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Buller R.
WESTPORT
Buller River

ON THE MOKIHINUI COALFIELD.

Report by A. McKay, Assistant Geologist.

5th August, 1886.

As directed, I left Wellington for Westport on the 9th July last, reaching Mokihinui on the 14th. From the 15th till the 26th I was engaged examining the various coal-outcrops, drives, shafts, and trial-works that have been discovered or made in connection with the exploration of the area between Page's Creek and the coast-range, or farther to the east along both banks of Coal Creek, and also made a number of observations bearing on the general disposition of the coal-seams and geological structure of the coal-bearing area south of the lower part of the Mokihinui Valley, east of the coast-range.

On the 27th and 28th I made examinations on the south bank of the Ngakawau, and from Mine Creek eastward to the higher levels of the plateau overlooking the middle course of the Ngakawau and the sources of Coal Creek and Page's Creek; and, leaving Westport on the evening of the 28th, arrived at Wellington on the following day, the 29th July.

Report.

About a mile inland from where it enters the sea the Mokihinui breaks through the coast-range, striking nearly north-and-south, and farther inland cuts the second range of old Palæozoic crystalline rocks, which disappear below coal-bearing and other Cretaceo-tertiary strata five to six miles east of the coast-line.

North of this part of the Mokihinui Valley the rocks developed are mainly the higher part of the Cretaceous system, and only a small area opposite the junction of Page's Creek can be said to belong to the lower or coal-bearing series; while on the south side of the river the rocks are mainly the lower beds, consisting of quartzose sandstones, grits, and shales, with valuable and at places thick seams of bituminous coal. From the upper part of Grant's Creek, on the east or inland side of the coast-range, to the western foot of the second range of crystalline rocks, the coal-bearing beds occupy a belt of country about four miles in width, and from the Mokihinui extend south to the Ngakawau, and thence are uninterruptedly continued as part of the Buller coalfield, terminating on Mount Rochfort.

Page's Creek and Coal Creek mainly drain the area of coal-bearing country that lies within the Mokihinui Valley back to the watershed, whence in a southerly direction the drainage flows into the Ngakawau. Coal Creek runs south at a short distance (half a mile or so) from the foot of the eastern or inland range of crystalline rocks, while Page's Creek runs north-west and north-north-west across the coal-bearing area, and in the lower part of its course is within a mile of the eastern slopes of the coast-range.

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It joins the Mokihinui a little to the east of where the present coal-mine is situated and the terminus of the railway.

Page's Creek runs along a deep narrow valley, the sides of which are exceedingly precipitous, and in the lower part of its course along the bottom of a narrow ravine, having vertical walls, hence sometimes called Chasm Creek. These abrupt slopes on the south-west side in a very short distance, less than a mile, rise to a height of 700ft. and 800ft., and farther to the westward blend with the higher eastern slopes of the coast-range that are south of the source of Grant's Creek. Grant's Creek runs along the foot of the coast-range, and joins the Mokihinui a mile and a half from its mouth. From between the source of Grant's Creek and the lower part of Page's Creek the slope towards the Mokihinui, though rugged and broken by numerous gullies, is gradual and regular, whether followed north-east to the junction of Page's Creek or north to a point opposite the junction of Stillwater Creek, coming from the north-east and entering the Mokihinui a mile and a quarter below the junction of Page's Creek.

Within this part of the field numerous coal outcrops have been discovered, and at all levels up to 700ft. above the sea. Nine of these outcrops I examined, and, although some of them are considered to be distinct seams from that which has been driven upon and followed to the rise of the coal a distance of 10 chains from near the railway terminus in a south-south-west direction, I could not satisfy myself that all these outcrops could be referred to more than two seams—that which has been opened out, and the small seam overlying, which shows on the north bank of the Mokihinui, also cut in the first shaft from the entrance of the mine.

This is made clear by taking into consideration the fact that the general slope of the country and the dip of the strata are the same within the area lying between the lower part of Page's Creek, Grant's Creek, and the Mokihinui River; and this conformity of the average surface-slope and the dip of the coal proves another important fact—viz., that in the shaft sunk 7 chains ahead of the mine-workings, and at a height of 235ft. above the sea, the horizon of the coal was passed at 50ft. to 54ft. from the surface, although only a band of shale was met with at that depth.

The incline driven on the rise of the coal from 2 to 3 chains south-east of the end of the railway is entered at 65ft. above sea-level, and bears in a direction 21° west of south, the distance driven being 10 chains. The dip near the entrance is nearly N., and the thickness of the coal, 4ft. to 5ft., in some places 6ft., is maintained for the first 7 chains, when a fault is met with, with a down-throw to S.E. of 6ft. to 7ft., beyond which the coal is parted by a band of shale which gradually increases in thickness till at the end of the drive, 10 chains from the entrance, only 1ft. or so of good coal underlies the sandstone roof.

At a distance of 5 chains from the entrance a heading has been driven to the westward some 60ft., and in this the coal at first maintained its maximum thickness, but towards the end of the drive rapidly diminished in thickness and was reduced to 2ft. 6in., showing signs of being troubled by a fault in this direction. Had these workings been pushed farther, a very little distance would have determined the amount of this throw, which appeared to me not great, and, as I judged, beyond it the coal would probably have recovered the thickness with which this heading was started. In the main drive beyond the 6ft. fault already mentioned, the coal for some distance dips to W.N.W., and at an angle greater than observed in other parts of the mine. At the extreme southern end of the workings the dip is variable, to N., and also N.W., at an angle of 10°. Taken altogether, the various observations show that the average dip is to N.N.W., and the average amount of dip 10°. The elevation at the inner end of the main drive 10 chains from the entrance is 135ft., or 70ft. above the point at which the mine is entered.

Directly in the line of the drive, and 17 chains from its entrance, a shaft has been sunk with the object of cutting the coal at 7 chains distance beyond the end of the drive, and according to the direction and dip of the strata and the height above sea-level the coal should have been met with at a depth from 50ft. to 60ft. As a matter of fact a band of shale 4ft. thick was passed through 50ft. from the surface, this shaft, 104ft. deep, having passed through the following thicknesses of grit and shale:—

Surface.	Feet.
Moderately coarse quartzose grit	50
Shale	4
Moderately coarse quartzose grit	46
Shale	1
Grit	3
Shale (not proved)	..
Total	104

As it is important to show that this shaft, 17 chains from the entrance to the mine, did cut the horizon of the coal at 50ft. from the surface, I may here state by what means this conclusion was arrived at. Having determined the average dip of the strata in this part of the field as being 10° in a N.N.W. direction, the rise of the coal is thus S.S.E. The main tunnel from the entrance to the mine has been driven in a direction S. 19° W., and consequently a little to the rise side of midway between the strike and the dip of the beds. The 10 chains that has been driven in this direction terminates in the face of the coal at an elevation of 135ft. above the sea, and, as the coal was entered on at 65ft., the floor of the drive thus rises 70ft. in the distance driven, thus grading nearly 1 in 10.

Supposing this grade continues to the point in the direct line of the tunnel at which the shaft has been sunk, or 7 chains farther

to the south-south-west, the coal should have been met with at this point, *i.e.*, in the shaft at 120ft. above the entrance to the mine, or 185ft. above sea-level, and, as a consequence, 50ft. from the surface, the elevation of the surface at the shaft being 235ft. There can therefore be no doubt that the shale-band commencing in the shaft at 50ft. from the surface represents the coal, and its presence confirms the indications showing in the mine that the coal followed in this direction would be wholly replaced by a band of shale.

The shaft has been sunk through this shale-band 4ft. thick and 50ft. into the underlying strata, and, although at 100ft. a thin bed of shale was met with and the sinking was again on shale when work was suspended, no indications of a coal-seam were met with, and thus there can be no doubt that the horizon of the coal was reached, as above stated, at 50ft. from the surface.

Were further proofs of this wanting, these are to be met with 2 chains farther to the south, where, in a deep narrow gully, the waters of which find their way into Page's Creek, coal shows at nearly the same level as it should have been met with in the shaft. Here there is about 2ft. 3in. of coal underlain and overlain by shale-bands about 2ft. thick; and there is some prospect that if further mined on in a westerly direction the thickness of the coal-seam would increase, and replace the upper 2ft. of shale between the coal as seen and the sandstone roof.

In the next deep gully to the south-south-west traces of coal are met with at about the elevation at which the seam described might be expected; but no seam *in sitú* was discovered.

Farther to the south-south-west, at about 25 or 30 chains south-west of Trig. G, two small coal-seams show at 700ft. above sea-level, and dip N.N.W. at an angle of 10°. The lower seam is about 2ft. to 2ft. 6in. thick (the thickness could not be accurately determined), and is parted from the upper seam (about 1ft. thick) by 3ft. of shale. This appears to be the same seam as that showing in the mine, though there was no means of determinately proving this, as the distance from the mine mouth could only be determined approximately.

In two of the gullies west of the mine before reaching Grant's Creek coal has been found, but these I concluded, for reasons similar to those already given, to be outcrops of the same seam as that seen in the mine, their position in relation to the strike of the beds at the mine mouth explaining why the coal appears, according to its location, at higher or lower levels. To the rise (S.E.) from the mouth of the mine the coal has again been met with overlooking the lower part of Page's Creek at 100ft. above sea-level, and its appearance here is to be accounted for in the same way.

On the north-east side of Page's Creek the coal appears dipping in the opposite direction, and it is apparent that the beds form a

low anticline between the eastern bank of Page's Creek and the end of the railway-line.

Along the eastern side of the coal-bearing area three outcrops of coal were examined in Coal Creek. In following the creek up from the road to the Mokihinui Reefs, rocks *in situ* are first met with at the first crossing, where a camp has been. Here are dark argillaceous muds considerably indurated and not clearly stratified, which a short distance higher up are apparently overlain by gritty sandstones, from beneath which similar rocks to the first-mentioned make their appearance in such a way as would indicate a dip to N.; but the beds are much disturbed, and observations along this part of the creek are not to be depended upon as indicating the general strike and dip of the strata in this part of the field. Higher up the creek, and before reaching the waterfall which is precipitated from the high cliffs bounding the valley on the west side, grits and gritty sandstones are seen in such a position as leads to the inference that from the vicinity of the waterfall the dip is to N., while from the waterfall up the valley the the dip is E. or S.E. At the waterfall, what may be considered as the lowest beds met with in this part of Coal Creek or north of the "big seam" appear at the base of the cliffs, as a conglomerate consisting of rolled fragments of quartz in a grey sandy matrix, the whole forming an exceedingly hard rock, of which large masses lie at the foot of the cliffs close to the waterfall.

Immediately higher up the creek these conglomerates disappear, and are followed by sandstones in the higher part of the cliff, between the upper beds of which and the conglomerates there is a probability of the occurrence of shales and coal-seams. Some such appearance is presented in the higher part of the cliff at the waterfall; but the cliffs are inaccessible at this point, and where these beds might be reached farther up the creek the bush and undergrowth prevent the ground being readily examined for any outcrop that may occur. The direction of this part of the valley of Coal Creek being north-and-south, from the foregoing it will naturally be inferred that the strike of the beds is in an E. or a N.E. direction; and such would indeed appear to be the case on the western bank of the creek, as far as the eastern bank of Page's Creek.

That the dip in this part of the field is, generally, to the S.E. I inferred from the general outlines of the country, and from the appearances presented by some rocky projections overlooking Page's Creek, a mile and a half or two miles above its junction with the Mokihinui.

On reaching the 10ft. seam, which is the first seam met with in following up Coal Creek, and at a distance of one mile from its junction with the Mokihinui, the dip proved to be E. at an angle of 10°. The drive which has been here entered upon the coal is put in almost directly to the dip, so that at the end of the drive, this

being kept level-free, one half of the coal is under foot. Along the east bank of the creek to the south the coal can be traced for a distance of 4 to 5 chains, and in this direction is not diminished in thickness, or faulted, as has been supposed, but simply crops out as, according to its strike and the configuration of the hill-slopes on this side of the creek, it of necessity must do. The position of the coal on this side of the creek is not very favourable to its being worked to advantage, and comparatively little can be won level-free.

Some 50 chains higher up the creek, and on the opposite bank, the coal again makes its appearance, but this time in such a manner and under such conditions that correct observations of the strike and dip cannot be readily obtained. On the east side of this outcrop there appear to be an old channel and shingle-terrace of the creek, which are reported to have been touched in the roof of the drive put in at this place. A few feet from the entrance the coal is disturbed and cut off, so that it is not traceable farther up the creek. Between this point and the first appearance of the coal down the stream, the bearing is N.–S. (magnetic), and the dip to E., which agrees with the observations made at the drive on the east side of the creek.

Beyond the fault, following the creek in a south direction, dark-coloured unstratified argillaceous rock, resembling that noted as first met with in following up the creek, is met with, and continues to the point where the "big seam" appears on the east bank, 50 chains above the drive entered on the 10ft. seam.

The coal here is said to be 18ft. thick, but as far as I could see its thickness has not been proved, and it may be that this is considerably more than given. Judging from the slight dips observed between the laminæ of the coal, it is where exposed nearly in a horizontal position, and, although the observations I made were of a contradictory character, I believe the coal will eventually be proved to dip at a low angle to S.E.

The coal of this seam is different in appearance from the 10ft. seam, and is somewhat of a tender character, but there are bands of strong coal in it, and, as no work has been done to prove what its character may be under cover of the overlying beds, no opinion as to its value in this respect can at the present time be relied on.

The 10ft. seam I noted as being 180ft. above the sea; the "big seam," half a mile farther up the creek, 230ft.

As regards further prospecting within the area west of Page's Creek, its eastern slopes into Page's Creek offer the best facilities for an examination of some 300ft. or 400ft. of strata underlying the coal-seam at present known, and, if a lower seam exists, its discovery should be a matter of no great difficulty. As far as my examination extended I discovered no bed that corresponds to the conglomerates and breccias that should lie at the base of the

formation, and there is ample scope for the occurrence of seams underlying that known and already partly opened out. This area might also be further prospected by a borehole, which, if located at the end of the railway-line, would commence in the dark shaly beds under the seam driven on, where a very considerable depth would have to be bored before reaching the basement rock under the coal-bearing series.

In the Coal Creek area further prospecting should be carried on prior to extending the railway in that direction, and such prospecting should have for its object to prove that the seams showing on either bank of Coal Creek extend westward in the direction of the middle course of Page's Creek, as in this direction they would offer the best facilities towards their being worked level-free.

As regards the area north of the Mokihinui River, there is but little of this that shows the grits and shales of the coal-bearing series at the surface. The grits and sandstones occupy the northern end of the low range opposite the junction of Page's Creek; but the northern end of this range, south of the lower part of Stillwater Creek, is composed of shaly mudstones and marly strata containing marine fossils, which, though prolonged considerably to the north, are to the north-east and north-west overlain by the limestones forming the higher part of the Cretaceo-tertiary formation, which is developed yet farther to the north as far as the Wanganui River.

South of the Mokihinui the coal-bearing area may be worked with advantage, as having the Port of Mokihinui for an outlet, or the railway from Westport extended thus far; but from the upper part of Page's Creek and Coal Creek the disposition of the strata and the fall towards the Ngakawau favour the output of the coal in this direction.

An examination of the coast-ranges south of the Mokihinui to the sources of Grant's Creek on the east side, and to Brewery Creek on the west side, showed but little probability of coal occurring there. The northern end of the range is formed of crystalline rocks; farther to the south, of Miocene Tertiary strata.

ON THE UPPER WANGANUI AND KING-COUNTRY.

REPORT BY JAMES PARK.

INSTRUCTIONS BY DR. HECTOR.

Wellington, 11th January, 1887.

I WISH you to start as early as possible for the interior of the North Island, to continue your work of last year in the Upper Wanganui and Mokau district.

In passing Marton you will examine and report upon the alluvial gold discovered there; and thence proceed to Karioi, and put yourself in communication with Mr. Rochfort, as arranged, for the purpose of investigating the alleged discovery of gold in the Waimarino Plains. Thence follow down the Manganui-a-te-ao, and, ascending the Wanganui River to the junction of Tangarakau, ascertain the nature of the gorge, and whether there is any natural feature to account for the sudden bend in the river. Thence examine the coal-outcrops in the Tangarakau, and follow the Wanganui and the proposed railway-line until you reach the tunnel at the source of the Mokau. Thence examine the country by the Mokau-iti, the Mokau, and the Awakino valleys, until you have cleared up the points that were left in doubt last year. Re-examine the coast sections at the Mokau River and north of the Awakino, to where the trachytes commence. Return by way of Stratford, and from there endeavour to ascertain the nature of the brown sandstone that forms the high ground between that and the Wanganui; and especially search for the formation that carries the graphite beds, of which specimens were sent to the Museum many years ago.

The chief points to be kept in view are—(1) the relation of the southern boundary of the coal-bearing rocks to the overlying Tertiaries; (2) also the relation of the White Cliff beds to the upper calcareous beds of the Waitotara series; (3) the relation of the calcareous beds over the coal at the mouth of the Mokau River to the calcareous beds in the Upper Mokau and Awakino Valleys, and the relative position they occupy to the coal formation; (4) the general question of whether the Waitotara limestone, which forms a well-defined zone characterized by *Ostrea ingens*, has been deposited during the gradual elevation of the land, amounting in the central district to over 4,000ft., or whether its elevation was entirely subsequent to its deposition at a uniform level beneath the sea; (5) the relation of the Ruapehu volcanic series along its western border to the older rocks and the Tertiary rocks.

JAMES HECTOR.

NARRATIVE.

Wellington, 29th August, 1887.

I HAVE the honour to report that, as instructed, I left Wellington on the 17th January, and proceeded to Marton, thence to Wanganui, and from there to Karioi by way of Field's Track. On the 20th I reached Ohakune, where I met Mr. Rochfort, as previously arranged. From the 21st to the 26th I was engaged examining the cuttings along the new road-line to Waimarino, where I also examined the localities where traces of gold were found last year by one of Mr. Rochfort's men. On the 27th I proceeded down the Manganui-a-te-ao to Ruakaka, and thence reached Pipiriki

the next day, where I made arrangements for starting up the Wanganui River to Taumarunui.

The first day, the 31st, I reached Utapu, fifteen miles distant, at noon, and spent the remainder of the day examining the open country towards the Waitotara, and making a collection of fossils from the limestone ledges opposite the Native settlement. Next day I proceeded up the river to the Tangarakau; and on the 2nd February to Kirikiriroa, on the way making a collection of fossils at Otapokiore.

During the next two days I examined the rugged bush-country between the Wanganui and the Heao, and on the succeeding four days proceeded to the Ohura, Paparoa Rapids, Te Maire, and Taumarunui, where I arrived on the 8th. On the 10th I followed the railway-line along the Ongaruhe Valley to Te Koura, and the next day reached the tunnel at Poro-otarao. From there I followed the railway-line into the Mangapeiha valley, and thence across the ridge into the Mokau valley. At a point about five miles from Te Kuiti I turned down this valley, and reached the Wairere Falls on the 12th.

On the 13th and 14th I examined the Mokauiti valley and the limestone gorge of the Mokau, about two miles above Totoro; and on the 15th, 16th, and 17th the Awakino valley. On the 18th I proceeded up the Mokau to the Torea, where I examined the old mail-track to the Awakino. The next day I proceeded to Mangatawa, and thence on the 20th to the Panirau. On the 21st I ascended the high ridge on the south side of the Mokau, situated about three miles from the Mokau coal-mine.

During the next two days I made a careful examination of the section from Patokatoka to the Mokau Heads, so as to determine the relation of the beds there to the limestone. On the 24th I proceeded up the coast to the Awakino, and thence to Waihi Stream. Next day I pushed north to Tirua Point, beyond which the coast is exceedingly broken and almost inaccessible.

On the 26th I proceeded down the coast to Urenui, and during the next three days examined the country between the coast and the head of the Makatui, a branch of the Mangaehu, which is one of the largest tributaries of the Patea. On the 2nd March I proceeded to Stratford, and thence followed the old Maori track to the head of the Waitotara, which I reached on the 5th. On the 8th I returned to Stratford, and proceeded to Manaia, where I examined the locality where the graphite was found some years ago. On the 12th I returned to Wellington.

REPORT.

Murimotu to Waimarino.—The Murimotu Plains have already been described by me, in last year's reports, as a succession of broad ascending terraces formed by the Wangaehu and its tributaries, the material consisting of rocks derived from Ruapehu.

The whole of the open tussock-land here is covered by a deposit of fine pumice-sand, which probably originated during some former eruptions of the volcanic mountains near the south end of Lake Taupo.

At the lower end of the plains occur several outcrops of shelly limestone (Te Aute), which is lying very flat, and can be traced eastward by a line of low escarpments that extends to Ruanui and the Hautapu; but, contrary to all experience, the limestone does not improve the soil of the plains, its influence being more than neutralised by the pumice-sand, which acts very banefully on the soil not only here, but wherever it is present.

The sections exposed in the cuttings along the new road from the Murimotu Plains to Waimarino are very interesting and instructive as regards the relation of the igneous rocks of Ruapehu and the young Tertiaries of this area.

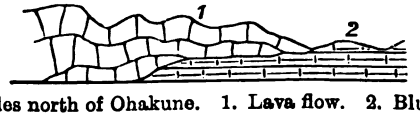
Two miles from Karioi the road enters the bush, which is moderately flat and unbroken all the way to Ohakune, a distance of seven miles. This place is a natural clearing a few acres in extent, situated on the east bank of the Mangawhero. It is close to the Main Trunk Railway-line, and is the point from which the new roads diverge to Waimarino, Karioi, and Pipiriki.

From the Murimotu Plains to the west side of the Mangawhero the country is almost level, and is occupied by volcanic conglomerates and tufas. From Raetihi, westward for about three miles, the country is more broken, but beyond this it is again flat and swampy till the Waimarino Plains are reached. This area is also occupied by the conglomerates and tufas; and it may be taken as a rule here that these rocks form level country, and the Tertiaries a rough broken surface.

The conglomerates and tufas continue two miles and a half past Ohakune, where they are seen resting unconformably on the blue sandy clays of the Tertiary series.

Section 2½ miles north of Ohakune. 1. Conglomerates and tufas. 2. Blue sandy clays.

Similar sections may be seen at many places on the road-line up to four miles and a quarter past Ohakune, where the sandy clays, which usually weather a rusty-brown colour at the surface, are overlain unconformably by a heavy lava-flow of a dark basic rock, which is finely vesicular throughout its entire mass, and quite scoriaceous at its upper surface and edges.



Section 4¼ miles north of Ohakune. 1. Lava flow. 2. Blue sandy clays.

At twelve miles from Ohakune the road crosses the Mangaturuturu, the waters of which are highly mineral and of a bluish milky colour, at all times giving off a strong sulphurous smell. It rises on the west side of Ruapehu, and probably has its source in the crater from which the Wangaehu, possessing similar mineral characters, also rises.

The conglomerates and tufas which cover the Waimarino Plains and all the country around Ruapehu are, in most cases, composed of well-waterworn material derived from this volcanic centre (which is the source of all the rivers in this district), and should more properly be called a volcanic drift, which is frequently consolidated into a hard conglomerate. They form a gradually-sloping plateau extending many miles west of Ruapehu; but a few miles west of the road-line they do not occur as a continuous deposit, being now confined to the river valleys as loose gravels forming high steep terraces, which sometimes reach almost to the Wanganui, and are the source of the volcanic rocks seen in the stony beaches on this river. They are deeply intersected by the tributaries of the Mangawhero and Manganui-a-te-ao, and in many of the deep ravines and gorges they show a thickness of 300ft. to 500ft., consisting of alternations of muds, sands, gravels, and boulders, some of which are 10ft. in diameter.

Waimarino to Wanganui River.—In proceeding down the Manganui-a-te-ao the volcanic drift was found to extend to the junction of the Mangahani, below which appeared soft yellow micaceous sandstones, which are underlain by a bed of shelly limestone about 15ft. thick. Most of the shells are badly preserved, but I could make out *Crypta incurva, Dosinia greyi, Pectunculus laticostatus, Callista elegans, Cardium striatulum,* and a large thick oyster which is probably *Ostrea ingens.* This limestone contains pebbles of slate and sandstone in such abundance that it might in most cases be called a shelly conglomerate. It is underlain by a great thickness of blue clays, which weather whitish-grey, and form steep cliffs, from 400ft. to 600ft. high, on the banks of the river at Ruakaka. These clays extend to the mouth of the Manganui-a-te-ao.

Pipiriki to Taumarunui.—The rocks crowning the high ranges around Pipiriki are brown micaceous sandstones, which are underlain by a bed of hard pebbly shell-limestone, which is in turn underlain by blue clays with hard concretions. The latter are well exposed in the road-cuttings near the boat-landing. They contain a number of minute fossils, of which a collection was made last year. A large collection of fossils was made from the limestone, most of which belong to recent species.

As far as Mangaio, four miles above Pipiriki, the dip is steadily S.E. at angles rarely exceeding 2°. Above this it gradually flattens and then changes to N.W.; but on account of the undu-

lating character of the beds it is difficult to estimate the thickness of the strata between the calcareous horizons.

About half a mile below the caves at Mangaio the blue clays are interbedded with a hard argillaceous band containing a number of fossils, of which the following were collected: *Cardium striatulum, Venus mesodesma, Trochita dilatata,* Echinus, and fish-teeth. At the caves the blue clays are interbedded with several beds of pebbly shell-limestone, from which a collection of fossils was made. The caves are narrow underground water-channels in the blue clays, with a limestone roof. They are called by the Maoris "Pararutu."

At the lower end of the Ngaporau rapids, two miles below the Manganui-a-te-ao, the beds are blue sandy clays and brown sandstones, which dip at low angles to N.N.W. Between this and a point 15 chains above the upper end of these rapids they are interbedded with four distinct bands of pebbly conglomerate, varying from 1ft. to 3ft. in thickness.

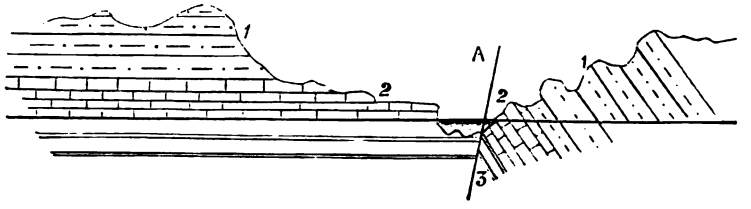
Above the Manganui-a-te-ao the Wanganui trends in a north-east direction and passes through the blue clays and sandstones as far as the Arawata Stream, near which the thin pebbly conglomerate bands are again seen in the banks of the river. At Utapu, a short distance farther up, the pebbly limestones, first seen at the Mangaio caves, are well exposed on the right bank of the river. A large collection of fossils was made here, including *Ostrea ingens, Pecten triphooki, Pectunculus laticostatus, Crypta incurva,* Dosinia sp., Heminactra sp., and a large number of broken Balanus. These beds are lying very flat, and are exposed in many places on the banks of the river as far as the Wangamomona River. The pebbles which constitute a large proportion of these limestone bands consist of grey and green sandstones, blue and red jasperoid slates, slate-breccias, and quartz.

Above the Tangarakau the rocks are blue sandy clays alternating with heavy-bedded brown sandstones. A mile below the Opurau they are interbedded with pebbly shell-beds, which appear to be the same as those seen at Utapu. At Otapokiore Rapids, two miles below Kirikiriroa, they are interbedded with another fossiliferous horizon consisting of pebbly shell-beds and argillaceous shelly layers. The fossils, of which a collection was made, are principally *Pectunculus laticostatus,* Anomia, Teredo, *Lutraria solida, Ostrea ingens, Hemimactra notata, Tapes intermedia,* Mytilus, *Voluta pacifica* (?), *Crypta incurva, Turritella tricincta, Trochita dilatata, Struthiolaria tuberculata, Dentalium solidum,* and Balanus.

At Kirikiriroa the dip is southerly at angles less than 3°. About two miles above this place the brown sandstones are slightly argillaceous, and have a tendency to weather in small concretions. Three miles higher up the river they are interbedded with shelly beds and conglomerate bands apparently the same as those seen at Otapokiore.

The brown sandstones which form the high broken country between the Heao and the Wanganui contain fossils in abundance, and at a point near the top of the ridge facing the Heao I collected the following forms: Teredo, Pecten, Cucullæa, Panopæa, *Turritella tricincta*, Murex, and *Dentalium solidum*.

Above the Retaruke are brown sandstones underlain by blue clays, which form high conspicuous cliffs on the banks of the river between this and Kirikau. They are interbedded with irregular bands of marlstone, which form flat projecting ledges. From the Ohura to the Otuiti they are lying almost flat, and, above the latter, pass down into soft brown sandstones and sandy clays, which in turn are underlain by blue crumbling sandy clays. Three miles above the mouth of the Kokakonui these are underlain by marly greensands, often gritty or pebbly, which contain fossils in great abundance. They are interbedded at their base with a hard calcareous marly-greensand band, almost a limestone, which is also crowded with fossils, of which a very large collection was made at the Paparoa Rapids a short distance higher up, where the river rushes through a narrow channel cut in these rocks.



A. Paparoa Rapids. 1. Blue sandy clays. 2. Marly greensands. 3. Thin-bedded dark-blue crumbling marly clays and harder sandy marls.

On the left bank of the river the beds are lying very flat, while on the right bank they dip E. at an angle of 45°, a fault or dislocation running parallel with the river at this point.

The following is a list of the fossils collected from the marly greensands: *Pectunculus laticostatus*, *P. cordatus*, Astarte, *Lima bullata*, *Pecten hochstetteri*, *P. burnetti*, *Zenatia acinaces*, Teredo, *Dosinia magna*, *D. greyi*, *Cardium multiradiatum*, *C. striatulum*, *Crassatella ampla*, *Cucullæa ponderosa*, Psammobia, *Corbula dubia*, *Panopæa sulcata* (?), Tellina, Venus, *Tapes intermedia*, *Waldheimia lenticularis* (?), *Crypta incurva*, *Turritella ambulacrum*, *Dentalium solidum*, Ancillaria sp. (?), *A. hebra*, *Struthiolaria tuberculata*, *S. canaliculata*, Struthiolaria, *Natica ovata*, *Trochita dilatata*, Voluta, fish-teeth, crab-remains, and corals.

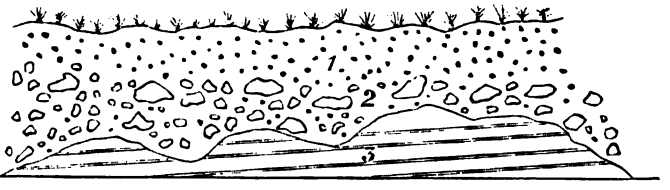
The most characteristic feature of these beds is the number of large bivalves, which are far more numerous than the other forms.

The marly greensands are underlain apparently quite conformably by dark-blue crumbling marly clays, which alternate every

few inches with harder marly bands. They are fossiliferous in their upper surface, containing a small Turritella, Dentalium, a number of small bivalves, Nodosaria and other Foraminifera.

For the first four or five miles above the Paparoa Rapids, the river passes over the upper beds (No. 1); but three miles from the Otunui it trends eastward, thus exposing the lower beds, so that at the mouth of the Otunui the fossiliferous marly greensands and dark marly clays are again seen on its banks. The dip being about N.W., still lower beds are exposed at Te Maire Stream, beyond which the river trends along the strike of the beds, thus carrying the same banded dark marly clays to Taumarunui. The lowest beds are seen about two miles above Te Maire, and consist here of dark crumbling marly clays alternating with brown or green sandstone layers in place of the finer marly layers in the higher part of these banded clays. The sandstones, which weather out as thin flags, contain thin streaks of carbonised wood and broken plant-remains. Somewhere to the east of Te Maire, where even lower beds would be exposed, judging from the dip, a seam of coal is reported to crop out in the banks of a small stream. Coal is also reported in some of the branches of the Retaruke.

About six miles above Whenuatere, situated near the Paparoa Rapids, the Wanganui River is bounded by open fern-terraces, composed of pumice-sands and gravels, which are generally underlain by a heavy river-drift, principally composed of trachy-dolerite, many large boulders of which are also dispersed through the overlying gravels.



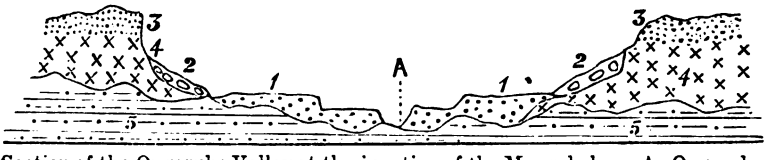
Section of bank of the Wanganui below Taumarunui. 1. Pumice-sands. 2. Gravels with trachy-dolerite boulders. 3. Banded clays.

From Pipiriki to the open fern-land, six miles above Whenuatere, the course of the Wanganui is through a narrow gorge, with steep precipitous walls, which renders it almost impossible to land except at the few Native settlements on the river, where the banks are lower, or ladders have been provided by which to reach the high terraces above.

The country on both sides of the river is extremely broken, consisting of deep V-shaped gullies and steep narrow ridges, which terminate abruptly at the river. There are no well-defined valleys, and even from the tops of the highest ridges it is impossible to trace the course of the river among the sea of hills and ridges which occupy the whole country. The course of the river is exceedingly tortuous, few of the reaches being over 20 chains in length.

Taumarunui to Poro-otarao Tunnel.—On the ridge between the Taringamutu and Opotiki Streams, which fall into the Ongaruhe River a few miles above Taumarunui, the blue banded clays are underlain by yellowish clays and fine-grained sandstones, which contain numerous Foraminifera and several minute molluscs, of which a collection was made. A short distance farther up this valley these beds are underlain by sulphurous greensands, which contain marine shells in great abundance. They are well exposed in the road-cuttings above Te Koura, where the following forms were collected: Voluta, Tellina, Zenatia, Nucula, and a small Turritella. The greensands are often interbedded with harder calcareous concretions, which generally enclose fragments of shells and fucoid stems. In most places they are slightly argillaceous and weather into concretions near the surface. The coal-seams reported in the Ongaruhe Valley probably occur near their base.

About a mile above Te Koura the tops of the ranges on both sides of the valley are capped by rhyolitic tufas, passing into solid rhyolite, which extend as a continuous deposit from Turanga, where they are 1,800ft. above the sea, to the head of the Ongaruhe, 700ft. above the sea. They are from 75ft. to 100ft. thick, and present steep escarpments to the valleys, having at a distance a similar appearance to those formed by horizontal calcareous strata. The lower part of this sheet or deposit is in most places a true rhyolite, which can be seen passing up into a less compact rhyolite, containing enclosures of fibrous pumice. Its upper surface is of a tufaceous character, being composed principally of pumice, quartz-grains, and fragments of rhyolite. The high pumice-terraces in the Ongaruhe Valley are composed of material derived from this tufa.



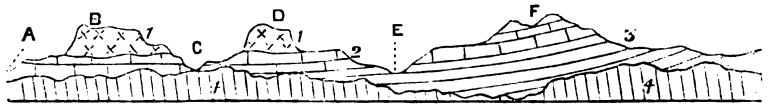
Section of the Ongaruhe Valley at the junction of the Mangakahu. A. Ongaruhe River. 1. Pumice-terraces. 2. Heavy slope-deposits. 3. Pumiceous tufa. 4. Solid rhyolite. 5. Sulphurous greensands.

Following the railway-line the rhyolitic rocks are found to descend to the level of the river at Waimeha, forming the extensive plains there, which in physical aspect closely resemble the Kaingaroa Plains, south of Tarawera. The high ridge on the watershed of the Ohinemoa and Mangapeiha is composed of greensands, weathering brown, and the overlying dark-blue banded marly strata. The tunnel at Poro-otarao is being cut through the latter.

Mangapeiha to Mokauiti.—Excepting the isolated patch of Cretaceo-tertiary rocks on the ridge between Herepu and the

tunnel, the whole of the area drained by the Upper Mokau, Mangapeiha, Mapara, Rangikohu, and Mokauiti Rivers appears to be occupied by the rhyolitic rocks first seen in the Ongaruhe Valley. They were traced from the Mangapeiha to the Mokau, and thence to "Gentle Annie," a high hill a few miles south of Te Kuiti; and from there southward along the left side of the Mokau valley to the Mokauiti.

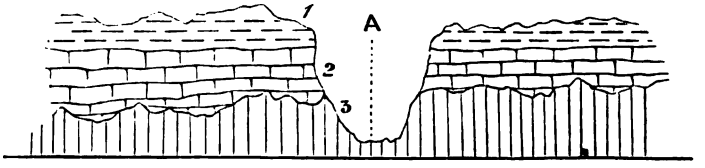
About a mile below Ngapingapi the Mokau limestone crosses to the right bank of the river, forming a low grassy spur. It rests directly on the old rocks at the Wairere Falls, where the actual point of contact is well exposed for examination. It is about 50ft. thick, and is lying almost horizontal; its lower layers, however, conform to the undulating denuded surface of the slaty shales and sandstones here, which dip to W. at an angle of 80°. Between the Mokau and Mokauiti it is overlain by the rhyolitic tufas, as shown in the following sketch:—



A. Mokau River. B. Aorangi. C. Rangikohu. D. Taumatine. E. Mokauiti. F. Whatangata. 1. Rhyolitic tufa. 2. Limestone. 3. Blue marly clays, passing down into brown sandstones with coal-seams. 4. Slaty shales and sandstones.

At the Mokauiti the limestone is principally composed of echinoderm remains; it also contains two species of Pecten, and fish-teeth, of which specimens were collected. At Te Rutu it is more earthy, and contains greenish specks like glauconite and dispersed pebbles of slaty shales and sandstone, which are, however, in places arranged in thin layers. About half a mile from Totoro it is interbedded with a bed of large oysters, probably *Ostrea wullerstorfi*. At the same place I also collected a large solid coral (Amphelia), two species of Pecten, and several bivalve and univalve molluscs, too indistinct to determine.

Below the Mokauiti the Mokau runs through a deep gorge which exposes the reoks shown in the following section:—



A. Mokau River. 1. Yellowish clays. 2. Limestone. 3. Shales and sandstones.

The yellowish clays lie conformably on the limestone, and contain a small Pecten and a number of Foraminifera. Last year I estimated the thickness of the limestone at 200ft., but on actual observation at this time I found it does not exceed 60ft.

The old rocks, which are well exposed in the bottom of the gorge, are fine-grained argillaceous sandstones alternating with yellowish or blue slaty shales, and occasional beds of coarser calcareous sandstone or grit, which contain small nests of coaly matter. The dip here is W. at an angle of 85°, the same as at the Wairere Falls; and, if this dip is continuous between these places, the thickness of these rocks cannot be less than 10,000ft. The old rocks occupy most of the low fern-hills between the Mokauiti and Totoro, the limestone occurring only as isolated patches on the higher grounds.

Awakino Valley.—The rocks in the upper part of the Awakino Valley are brown sandstones and blue sandy clays, which farther down the river are overlain by brown ferruginous sandstones that form the high hills and ranges between the Mokau and Awakino Rivers.

The shingle in the bed of the Awakino is composed principally of argillaceous sandstones and shales very similar to those seen at the Mokau gorge above Totoro; but on account of the rugged and bush-covered character of the country none of these rocks could be found *in situ* in the upper part of the valley, and only in one instance could they be seen in the lower part. At a point about fifteen miles from the mouth of the river, in the bed of a small stream flowing from the north, there is an outcrop of sandstones and shales, from which I obtained a few fossils that indicate a Secondary age for these rocks. They dip W. at very high angles, and are overlain unconformably by fine-grained argillaceous sandstones belonging to the Cretaceo-tertiary series.

Fragments of coal are abundant in almost every creek that joins the Awakino in the upper part of its course. Volcanic rocks are extremely rare in any part of this river, a few trachyte pebbles being all I could discover. About nineteen miles from the mouth of the river the limestone crosses the valley and passes southward toward the head of the Manga-awakino. It is still about 50ft. thick, and is interbedded in blue marly clays and greensands, which weather brown. The limestone is seen at many places between this and a point about three miles from the mouth of the river, where it occurs at water-level, dipping W. at a low angle.

Lower Mokau Valley. — During this trip I revisited the Panirau, with a view of ascertaining the nature of the rocks occupying the top of the precipitous ridge which stands between that stream and the Turanga-apo. On examination, I found these to be brown sandstones—apparently an extension of those forming the Papakauri Range, on the north side of the Mokau. A short distance above the Panirau these sandstones, which contain a 3ft. coal-seam, are underlain conformably by blue sandy clays alternating with bands of hard blue marlstone, in which I found a small Turritella and a Pecten.

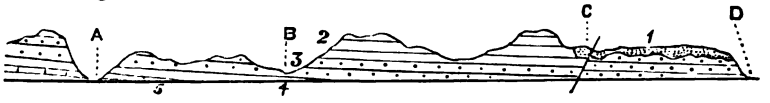
At the time I also examined the high ridge on the south side

of the river and about three miles from the Mokau Coal-mine, where the following rocks are seen in descending order:—

1. Greensands weathering brown, interbedded with blue crumbling clays; thickness, about 200ft.
2. Flaggy limestone, 40ft., composed of echinoderm remains and Foraminifera.
3. Thin bed of pale-blue crumbling marly clay, containing small bivalves and Foraminifera.
4. Sandstones, brown on surface, green in solid, interbedded with marly clays containing large calcareous concretions, which enclose fossils in great abundance.
5. Coal-seam near base; 3ft.

Last year I estimated the thickness of strata between the limestone and coal at 500ft. I now find it is at least 1,000ft.

In order to determine the relation of the limestone to the rocks at the Mokau Heads I made a careful examination of the section from Patokatoka to the sea, with the result shown in the following sketch:—



Section Patokatoka to Mokau Heads. A. Patokatoka. B. Tauwhare. C. Zig-zag. D. Mokau Heads. 1. Ferruginous trachyte sands and gravels. 2. Yellowish-brown micaceous sandstones, with thin beds of blue clays. 3. Thin-bedded tufaceous clays, grits, and sandstones. 4. Brown sandstones interbedded with blue sandy clays. 5. Limestone. 6. Brown sandstones.

The tufaceous sandstones at the heads are often calcareous, and weather out as thin ledges. They are generally of a grey colour, and vary considerably in texture, passing in places into coarse gritty beds composed of volcanic material. They contain a small flattened bivalve too indistinct to be determined.

Mokau Heads to Tirua Point.—The coast for several miles north of the Mokau is occupied by a fringe of low sandhills, and no rocks are seen till the Awakino is reached, where the ferruginous sandstones and underlying tufaceous strata are well exposed on the right bank. From this place to Tirua Point the tufaceous strata form high precipitous cliffs, along the base of which large tumbled blocks of rock are strewn so thickly as to render the coast almost impassable and difficult to examine, as it is impossible to get along the foot of the cliffs except at low-water.

North of Petone Point the beds have been greatly faulted and disturbed, and in many places exhibit a perfect maze of sharp contortions and plications. The tufaceous sandstones are sometimes gritty or pebbly, and pass into conglomerate bands. The pebbles are composed of trachytic rocks. The whole of these rocks are calcareous; and the finer clay or mud bands, ranging from a few inches to 2ft. in thickness, have the character of highly-indurated marlstones, and weather out in the face of the cliffs in a very distinct manner, and, where highly contorted,

present a somewhat remarkable appearance, which might lead to the belief, on casual observation, that they were lava-flows and not sedimentary rocks.

A large number of rock-specimens were collected between Waihi and Tirua Point.

Waitara District.—The first few miles east of Urenui are occupied by the Pleistocene drift of the coast, which rises in many places to a height of 500ft. above the sea, forming broad flat spurs and ridges, generally covered by scrub or forest. Between this and the Waitara valley the country consists of steep razor-back ridges, which in many places are only just wide enough for the pack-track. The rocks forming this rough area are blue clays, lying almost flat.

The valley of the Waitara itself is less broken; in fact, much of it is suitable for pastoral purposes, being occupied by the drift which forms wide flat terraces at its lower end. The country between the Waitara and Makatui is very steep and broken, being formed of blue clays, which are well exposed in all the slips and scarps.

The pebbly shell-beds seen on the coast at Onaira and Urenui are well developed in the valleys of the Makara and Taramokau Streams, and on the ridge at the source of the Makatui, and at all these places are overlain conformably by blue clays, which are followed by brown sandstones, usually more or less micaceous.

Stratford to Source of Waitotara.—Passing eastward from Stratford, the first twelve miles are almost flat, being occupied by the volcanic drift which everywhere sustains a dense forest-vegetation. Beyond this the country is exceedingly broken, being intersected in all directions by deep ravines and gullies. The rocks forming this area are brown sandstones, which often alternate with blue clays, and are interbedded at their base with pebbly shell-beds, apparently the same as those at Urenui. On the top of Mount Humphreys, at the source of the Waitotara, there is a fossiliferous bed containing *Ostrea edulis*, Dosinia, Pecten, and Turritella in great abundance.

Graphite Discovery near Manaia.—At Urenui I was fortunate enough to meet Mr. J. White, who found the graphite sent to the Colonial Museum about seven years ago. The original boulder was about 1ft. in diameter, and had a mass of brown sandstone adhering to one side. It was found in the bed of the Kapokonui River, about 3 chains below the bridge on the main road from Hawera to Opunake. I carefully examined the locality indicated, and the bed of the river for some distance both above and below the bridge, but I could find no trace of sedimentary rocks in the river-shingle, or in any of the numerous small streams that intersect the Waimate Plains. This graphite is probably a coal that has been altered by volcanic heat, and ejected by Mount Egmont during the period of its activity.

CLASSIFICATION.

The greater portion of the area forming the subject of this report is exceedingly rugged, and, being covered with a heavy forest vegetation, is, in many places, quite inacessible; consequently I was compelled, in pursuing my investigations, to follow the main lines of communication in most cases, and as a natural result the observations contained in the preceding pages affect but a small part of this area, and, being often disconnected, and in many cases necessarily incomplete, are difficult to reduce to a systematic arrangement.

The classification of the rocks in this district proposed for the present is as follows:—

I. Recent and Pleistocene—
  a. Alluvial flats and terraces.
  b. Volcanic drifts and tufas.
II. Pliocene—
  a. Rhyolitic tufas, passing into solid flows.
  b. Basic lava-flow.
III. Upper Miocene—
  a. Te Auto series. Brown sandstones and blue clays, with pebbly shell-beds and limestones.
  b. Taueru series. Sandstones and blue clays, with pebbly argillaceous shell-beds.
IV. Lower Miocene—
  a. Awamoa series. Blue crumbling sandy clays, underlain by marly greensands, with fossils.
VI. Cretaceo-tertiary—
  a. Yellowish sandy clays near Totoro.
  b. Mokau limestone.
  c. Thin-bedded blue clays.
  d. Greensands, with coal.
Lower Secondary (?)—
  a. Argillaceous sandstones and slaty shales.

I. Recent and Pleistocene.

a. *Alluvial Flats and Terraces.*—The largest alluvial flat in this district is situated in the upper Mokau valley, between the Native settlements Ngaruawahia and Ngapingapi. It comprises an area of about two thousand acres of rich grass land, most of which is well adapted for agricultural purposes, and at present supports a large Native population. Smaller flats, mostly a few hundred acres in extent, exist at Taumarunui, Taringamutu, Waimeha, and Mokauiti.

The only terraces worth mention are confined to the Wanganui valley, south of Taumarunui; and the Ongaruhe valley. At the former place they are of wide extent, but of little value, being largely composed of pumice-sand.

b. *Volcanic Drifts and Tufas.*—These occupy the lower flanks of Ruapehu, extending as a sloping plateau to a point several miles west of the railway-line, beyond which there is a sudden drop of from 500ft. to 800ft. on to the lower but more broken country formed by the sandstones and clays of the underlying Tertiaries. This plateau is deeply intersected by the Manganui-

a-te-ao and its tributaries, and in many of their gorges a thickness of 500ft. of this tufa-like drift is exposed without reaching bottom.

II. Pliocene.

a. *Rhyolitic Tufas, passing into Solid Flows.*—These have their principal development between the Ongaruhe and Mokau on their eastern and western boundaries, and the Mokauiti and Waipa on their north and south limits. They appear to have formed a continuous sheet over the whole of this area at one time, but now they exist only as isolated patches, forming flat-topped hills and ridges, except in the higher part of the Ongaruhe valley, where they descend to the low grounds and have been subjected to less denudation. Near Waimeha they pass into solid lava-flows, forming sharp pinnacles and bosses, which stand high above the level of the plains.

Specimens of the rhyolites were collected at the Rangikohu, Mangapeiha, and Ongaruhe valleys, and it is important to note that they are identical with the auriferous rhyolites recently discovered at Waitoa, Auckland. Gold has already been found in the Upper Wanganui and Ongaruhe; in the Rangikohu, Mangapeiha, and Upper Mokau; and it would be interesting to trace it to the rhyolites which cover all the country drained by those rivers, as in the event of their proving auriferous there is still the possibility of an extensive goldfield in the King country.

b. *Basic Lava Flow.*—This flow descends from the south-west flanks of Ruapehu, and crosses the new road from Karioi to Waimarino at a point four miles and a quarter north of Ohakune. It is lying on a denuded surface of the young Tertiaries, but there is nothing to show whether it is younger or older than the rhyolites just described.

III. Upper Miocene.

a. *Te Aute Series.*—This series includes the sandstones and blue clays between Pipiriki and the Tangarakau. They are interbedded with a number of thin conglomerate bands and pebbly shell-beds or limestones, which are specially characterized by the presence of *Ostrea ingens, Hemimactra notata,* and *Lutraria solida.*

b. *Taueru Series.*—The beds included under this head are sandstones and blue clays extending from the Tangarakau to the Retaruke. The division, however, between them and the overlying series is not marked by any change of the physical character of the rocks, but is entirely arbitrary, and consequently subject to revision at any time. At Otapokiore they are interbedded with argillaceous pebbly shell-beds, which contain all the characteristic fossils of the Taueru clays; of the Mohaka crossing-beds, Hawke's Bay; and of the lower fossiliferous horizon at Erehwon (600ft. below the Balanus or Te Aute limestone).

IV. Lower Miocene.

a. *Awamoa Series.*—This series is typically developed between the Paparoa rapids, at Whenuatere, and the Otunui Stream. They consist of blue crumbling sandy clays, underlain by fossiliferous marly greensands, often gritty or pebbly, and interbedded at their base with hard calcareous bands of gritty greensands containing the same fossils. The most characteristic forms are—*Cucullæa ponderosa, Pectunculus laticostatus, Cardium multiradiatum, Dosinia greyi, Crassatella ampla, Pecten hochstetteri,* and *Dentalium solidum,* all of which are found at the base of the Pareora or Awamoa formation in other parts of New Zealand.

VI. Cretaceo-tertiary.

The rocks of this formation extend from the Retaruke to Taumarunui, and thence along the Ongaruhe valley to the Upper Mokau, where they are obscured by the rhyolite tufas. Coal occurs at the base of the greensands at the Retaruhe, Ongaruhe, and Mokauiti valleys; but, so far as I could ascertain, none of the seams is thick enough to be workable. The limestone which is so largely developed in the Mokau valley is absent in the Wanganui area.

Lower Secondary (?).

The rocks included under this head are certain fossiliferous sandstones and slaty shales in the lower part of the Awakino valley. The sandstones and shales in the Mokau Gorge and at the Wairere Falls closely resemble them in physical character, and have more the appearance of Secondary than Palæozoic strata.

ON THE GEOLOGY OF EAST AUCKLAND AND THE NORTHERN DISTRICT OF HAWKE'S BAY.

REPORT BY ALEXANDER MCKAY, ASSISTANT GEOLOGIST.

NARRATIVE.

Wellington, 14th September, 1887.

I LEFT Wellington on the 10th November, 1886, and reached Woodville the same day. On the 11th I went to Takapau, and examined that neighbourhood on the 12th; on the 13th Waipukurau, Mount Vernon, and Waipawa; and on the 14th the banks of the Waipawa River, north-west to the limestone range on the east of the Ruataniwha Plain.

On the 15th I went to Kaikoura and Patangata, and on the 16th to the coast at Manawarakau and Te Apiti; on the 17th to Red Island and Waimarama; on the 18th along the coast and inland to the Tukituki Ford, Havelock, and Kaikoura; and

from the latter place on the 19th to Napier. On the 20th I went to Petane, where I was employed till the 22nd. On the 23rd and 24th I examined the Esk Valley to Dobble's, and Kaiwaka Creek to the big cutting on the Napier–Taupo Road. On the 25th it rained. On the 26th I examined the left bank of the lower part of the Esk River and the hills adjacent, and on the 27th the hills on the opposite side of the valley. From the 28th November till the 5th December I examined and collected from the section beginning with the limestone east of Dobble's, and thence continued north-west to Pohui and across Te Whaka Range to the north-west side of the Mohaka valley, Te Puretu Creek, &c.; and on the 6th the eastern side of the Mohaka valley north-east of the Taupo Road, and the slopes of the Maungaharuru Range. Packed collections on the 7th, and on the 8th went to Horoto, Tarawera, and Pukerinui Hill, and returned to Mohaka Bridge on the 9th. On the 10th I went to Pohui, and traced the higher band of limestone south-west of Pohui Lake; and on the 11th, in the opposite direction, the same beds four miles to the north-east. On the 12th I returned to Petane, and on the 13th collected from the Petane beds on the shores of Napier Harbour. On the 14th I went to Napier, and on the 15th to Taradale, Red Cliff, and Puketapu; on the 17th to Petane and back to Napier; and on the 18th examined the western part of the Cape Kidnappers section. Subsequently, till the 21st, I was engaged packing and despatching collections. On the 22nd stormy weather detained me in Napier, but on the 23rd I left for the mouth of the Mohaka River, where I arrived on the 24th, and remained collecting till the 28th. On the 29th I went to Clyde, on the Wairoa River, and was employed in that neighbourhood on the 30th and 31st. On the 1st January, 1887, I went to Oruamatua, north of Mahia Peninsula; on the 2nd to Mahia Township; on the 3rd to Whangawehi station and the mouth of Whangawehi Creek; on the 4th to Kinikini and Long Point, where I remained on the 5th, returning to Whangawehi on the 6th. On the 7th examined mainland from Oruamatua to Paretu; and on the 8th returned to Clyde, where I was employed on the 9th and the 10th.

On the 11th I started for Waikare-moana Lake, which was reached on the 12th and crossed on the 13th; on the 14th crossed the mountains to the source of the Whakatane River; on the 15th reached Ahikereru, and thence went to Galatea on the 16th. On the 17th crossed the Kaingaroa Plain, and on the 18th examined the country south of the line of volcanic disturbance; and on the 19th went to Rotorua. I remained in the hot-lake district till the 28th, on which day I went to Tauranga and thence to Opotiki, where I arrived on the 29th. I stayed at Opotiki till the 2nd of February, on the afternoon of which I went to Omurimutu; on the 3rd to the Motu River; on the 4th to Omaio Bay; and on

the 5th to Te Kaha, where I made examinations till the 8th. On the 9th I went to Raukokore; on the 10th to Oreti Point and Waihou Bay; on the 11th and 12th examined the Secondary rocks on the coast-line north of the mouth of the Raukokore River, and on the 13th and 14th the Raukokore River to the junction of the Waikura. On the 15th I went to Whangaparaoa. On the 16th rain threatened to flood the rivers, and I took a passage from Whangaparaoa to Hicks Bay, but was carried on to Awanui, where I landed on the 18th. From the 18th till the 22nd I collected in the neighbourhood of Awanui. On the 23rd I examined the rocks in the vicinity of East Cape; on the 24th went to Rotokautuku and the Tupuwaeroa River; on the 25th to Matahea, where I remained on the 26th. On the 27th I went to the Ihungia; and on the 28th to the Upper Mata. On the 3rd of March I returned to the Ihungia, and followed that stream to its junction with the Mata, and on the 4th the Mata and Waingakia Rivers to the southern slopes of Hikurangi. On the 5th the Mata, below the junction of the Ihungia, was examined, and in the afternoon I went to the coast at Waipiro. On the 6th I went to Awanui, and returned to Waipiro on the 8th; on the 9th collected at Akuakua; on the 10th came to Tokomaru, and on the 11th to Tologa Bay, and reached Gisborne on the 13th. I remained on the 14th in Gisborne; on the 15th I reached the entrance to the bush on the Gisborne–Opotiki Road, the Motu Bridge on the 16th, and returned to Gisborne on the 18th, and reached (by steamer) Napier on the 19th. On the 20th I was at Petane; and on the 21st went along the coast north to the Waikare River; on the 22nd to the source of that river; and on the 24th returned to Petane, and to Napier on the 25th. On the 26th I again examined and collected from the rocks of Scinde Island. On the 27th I left Napier, and arrived at Wellington on the 28th of March.

REPORT.

The examinations made during the period detailed in the preceding narrative extended over an area of nine thousand square miles, an area so considerable that of the whole only a very general account of its geology can be given. Considerable tracts were scarcely examined at all, and are mapped according to what was observed along the lines of journey already detailed and previous surveys made within the district dealt with. Between Napier and Poverty Bay most of the sections from the coast-line to the Palæozoic rocks of the interior show a regular sequence of strata dipping eastward; the strike of the beds is regular, and the boundaries of the different formations as mapped have been laid down from one known point to another with, it is hoped, a tolerable degree of certainty. Mr. Percy Smith has mapped the geology of the northern district of Hawke's Bay, and Mr. Cox the district from Poverty Bay to Napier, and, as far as there

is agreement respecting boundaries between their work and my own, I have availed myself of their results. In the same way I shall deal with the district between Gisborne and East Cape, mapped by Dr. Hector in 1874, and the east shore of the Bay of Plenty, mapped by Mr. Cox in 1877.

The southern part of Hawke's Bay District was not examined so as to warrant alteration of the formation-boundaries excepting on the south-east slope of Mount Vernon, but evidence near Taradale seems to require that the Cape Kidnappers gravels should be considered Pleistocene, and not Pliocene as previously classified.

Classification.

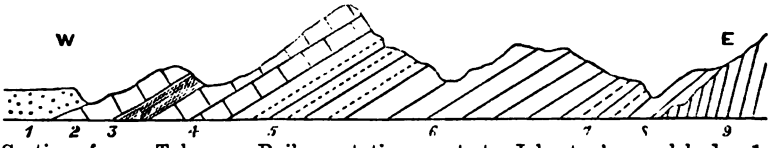
Formation.	Local Series.	Characteristic Local Beds.
I. Recent ..	Alluvial, æolian littoral	
Ia. Pleistocene..	Patangata ..	*a.* Patangata beds (conglomerate, sands, clays).
II. Younger Pliocene ..	Petane ..	*a.* Mahia beds (sands). *b.* Waipatiki beds (shelly limestone, sandy clays). *c.* Kaiwaka beds (conglomerate, sands, clays).
IIa. Older Pliocene ..	Pohui ..	*a.* Rangimapapa beds (conglomerate, sands). *b.* Pohui beds (grey and brown sands). *c.* Te Whaka beds (limestone and sands).
III. Upper Miocene ..	Mohaka ..	*a.* Titiokura beds (brown sands, sandy clay).
IV. Lower Miocene ..	Waikare-moana ..	*b.* Te Haroto beds (brown and grey sands). *a.* Waikare-moana beds (gritty sandstones and marly mudstones). *b.* Akuakua beds (sandy clay-marls). *c.* Ihungia beds (conglomerate and shales).
VI. Cretaceo-tertiary ..	Turanganui ..	*a.* Waikohu beds (limestone and grey sand). *b.* Turanganui beds (marly beds). *c.* Mata River beds (limestones). *d.* Wharariki beds (grey grit, conglomerate marls, and black shales).
VII. Lower Greensands ..	Awanui ..	*a.* Waipiro beds (grey contorted sandstones). *b.* Taitai beds (sandstones and shales, crushed). *c.* Mata River beds (green and dark-grey flaggy sandstones).
X.-XII. Trias to Carboniferous	Motu ..	*a.* Te Kaha beds (indurated sands and shales, jasperoid slates).
Volcanic— A. Acidic. B. Basic.		

A general description of the geology of southern Hawke's Bay having been already given in the reports for previous years (Geological Reports, 1874–76 and 1876–77), it is not necessary to do more than describe the different sections examined in this part of the district, and make the required corrections on the map accompanying this report.

TAKAPAU SECTION.

The section from Takapau Railway-station east to the base of the Tertiary sequence and outcrop of old Secondary rocks on Johnston's run (see Geological Reports, 1876–77, p. 70) was again examined, principally with the object of comparing the beds that underlie the Te Aute limestone with those on the south-east slope of Mount Vernon.

The following section shows the sequence of the beds; distance, about two miles :—



Section from Takapau Railway-station east to Johnston's woolshed. 1. Gravels of Ruataniwha Plain. 2. Band of shelly limestone. 3. Sandy clay-marls (not clearly seen in this section, but showing farther north). 4. Lower thick band of Te Aute limestone. 5. Brown sands, and grey sandy clays with shells. 6. Grey sandy beds, fossiliferous. 7. Grey sandy beds, with bands of brown and green sands, the latter full of small shells and Foraminifera. 8. White clays, with minute plant-fragments. 9. Old Secondary rocks forming Woolshed Hill.

Bed No. 2 of this section consists of shells, among which as prominent shells are *Ostrea edulis*, and casts of a small Venus, probably *V. mesodosma*. Bed No. 3, as stated, is not clearly seen in this section, but close to Johnston's home-station it is seen to part Beds Nos. 2 and 4, and where exposed in the banks of the creek consists of marly and sandy clays full of fossils, mostly so tender that whole specimens, save of a few species, are obtained with the greatest difficulty; and they seem almost wholly to belong to recent species.

Bed No. 4, the lower and thickest band of the Te Aute limestone, in its upper part is hard consolidated rock, containing a variety of shells, but, with the exceptions of *Ostrea edulis*, *O. ingens*, and *Pecten triphooki*, they occur usually as casts. The lower part of this upper division of Bed No. 4 is much softer than the upper exposed surface, and consists almost wholly of comminuted Balanus shells. At one place a massive branching coral forms a bed about 12in. thick, and in the Balanus sands *Ostrea ingens* occurs, but is not found higher or lower in the section. Underneath the Balanus sands is a soft yellowish calcareous sandstone, having a thickness not far short of 100ft., which, though wholly formed of shell-sand, contains but few perfect fossils, the

only species collected being *Pecten triphooki* and *Waldheimia lenticularis*.

These calcareous rocks, including the intermediate marly beds obscured in the section, have a thickness of from 100ft. to 130ft., and, in so far as there is a double band of limestones separated by beds in which the proportion of calcareous matter is much less, these agree remarkably with what is seen at many places in the northern part of Hawke's Bay, where not only the calcareous beds generally considered the equivalents of these are so parted, but the much younger Petane limestone is divided in the same manner.

Beds No. 5, brown and grey sandy beds, underlie the Te Aute limestone conformably, and contain a considerable number of fossils. Lying conformably under these are Beds No. 6, which are light- and dark-grey sandy beds, and Beds No. 7, similar beds, but with bands of brown and greenish soft sandstone, the latter abounding in Foraminifera and minute shells. From these beds *Dentalium nanum*, *D. læve*, and *Limopsis aurita* were collected, and from the beds a number of other species might be obtained, but, as in the other less calcareous beds of the section, all the fossils are in a tender condition, and difficult to extract without being broken. Bed No. 7, the last of the Tertiary sequence in this section, is a thick bed of white clay seen not far from the outcrop of the old Secondary rocks forming Woolshed Hill, and, though it is possible that the contact may be made by rocks of a different character, this is unlikely; and, even if this were so, such bed or beds could have no great thickness. The lowest rocks seen contain no fossils other than broken plant-remains, and in appearance are not unlike the beds on the east bank of the Mohaka, where the Napier–Taupo Road crosses the river.

Mount Vernon.

When I examined, in 1878, this part of the district I referred some beds on the left bank of the Tukituki to the Wanganui formation, and, as these lay east of the scarp of the Te Aute limestone, considered them unconformable to the limestones and beds that might underlie. From the beds in question I collected *Waldheimia lenticularis*, which occurred in a loose sandy matrix showing in the banks of a narrow ravine passing Mr. Harding's house, but obtained no fossils from the beds on which this rested; and, the lower beds showing no clear stratification, the whole were referred to the younger series, and in the report which followed were represented as highly unconformable to the calcareous series (Geological Reports, 1878–79, p. 72). This representation of the relation of the Wanganui formation to the Te Aute limestone is referred to by Professor Hutton, amongst others, as the strongest proof of the unconformity which he seeks to demonstrate as separating his "Ahuriri" and "Petane" series (Trans. N.Z. Inst.,

1885, Vol. XVIII., p. 343); but, as elsewhere I have not been able to confirm this view of the relationship of the beds, I was naturally led to again and more carefully examine the locality, the evidence elsewhere suggesting the possibility that in the first instance there had been an incorrect reading of this section. Improvements carried on by Mr. Harding have obscured the original outcrop, so that this could not be examined, nor indeed could the precise spot be identified. Towards the head of the gully an outcrop of rock was found, from which a number of fossils were obtained, but these clearly indicated the beds that underlie the Te Aute limestone in the Takapau section, so that I am compelled to give an interpretation to this section different from that given in the report of 1878–79, quoted above. The greater part of the beds shown in the section referred to as being younger than and unconformable to the Te Aute limestone must be considered as underlying and conformable thereto, while the bed whence the fossils were then obtained must be considered either of Pleistocene age or a rewash from the younger Tertiary beds in which were included some shells derived from beds of the Wanganui formation present in the district farther to the west. Probably this last conclusion is the correct one. I should not have thought it necessary to make this explanation but for the fact that the section as formerly described is the principal, most direct, and strongest evidence put forward by Professor Hutton in support of an unconformity between his Wanganui formation and the series to which the Te Aute limestone belongs.

WAIPAWA GORGE.

During a former examination of the Cretaceo-tertiary rocks exposed along the banks of the Waipawa River above the railway-line and Main South Road, I obtained one specimen of an ammonite (*Ammonites McKayi*, Catalogue of Indian and Colonial Exhibition, p. 57) and several specimens of Foraminifera, and during the past season again examined the section through the Waipawa Gorge, in the hope of adding to this collection. The fossils occur in a white or pale-yellow argillaceous sandstone that at first sight resembles the Amuri limestone, but is not, or but slightly, calcareous. Many Foraminifera, chiefly Nodosaria, were on this last occasion collected, and two species of bivalve shells, one of which appears to be *Venus selwynensis*, Hector (MS.), and the other, too imperfect for correct identification, seems to be a Solenella, found in the same series at Awanui. Blue argillaceous beds with spherical concretions underlie these beds, and underneath the latter is a black micaceous bituminous shale or mudstone, from which fish-scales and Foraminifera were obtained. This carbonaceous shale agrees in character and position with the bituminous shale of Awanui, and, on analysis in the Colonial Laboratory, proved to contain 12 per cent. of carbonaceous matter. This

shale or the like occurring in the equivalent horizon at Rotokautuku, in the Waiapu Valley, is supposed by Professor Hutton to be the source of the petroleum oil sought for on the Southern Cross lease. It has a remarkably wide distribution and constancy of character over the whole of the east coast of the North Island, including the North Auckland Peninsula, wherever the formation to which it belongs is present, and in the same formation it is present in the Marlborough and Otago Districts of the South Island. The Cretaceo-tertiary rocks of the Waipawa Gorge disappear under the Tertiary beds (Te Aute limestone and underlying beds) to the westward. Of these, the beds under the limestone are not more than 100ft. thick, and farther to the north-east, at Kaikoura and Te Aute, appear at places to be absent altogether, but have again a considerable thickness yet farther to the north before reaching to the Ngaruroro River.

Patangata.

In 1878 I discovered lacustrine beds on the banks of the Waipawa River, on the road between Kaikoura and Patangata (Geological Reports, 1878–79, p. 74). I did not further examine these beds; but in the banks of the Tukituki, at Patangata, I found beds of plastic clay associated with beds of lignite, which contain fresh-water shells in abundance, and which on the east side of the valley are overlain by coarse sandstone gravels.

These clays and gravels form hills rising 400ft. to 500ft. above the river-flats, and extend north for some distance, but perhaps not beyond the junction of Hawea Creek. At Patangata Ford the lowest beds cannot be clearly seen; but under the lowest lignite bed seen—about 2ft. thick—is an indurated calcareous rock or marlstone of a greenish colour; and close to the outcrop of the Upper Miocene strata (forming a high cliff on the east bank of the river above the ford) masses of ironstone full of plant-remains are found on the surface of the spurs within the boundary of the lacustrine beds as determined by the disappearance of the older series. This ironstone, judging from its weight and appearance, is of very good quality, but it could not be found *in situ*, and the few boulders met with on the surface may not indicate in what quantities it will be found if the beds whence they have come should be discovered.

Among the fresh-water shells of the clays overlying the lignite, a large form of Unio, having a very massive shell, is the most prominent and occurs abundantly, but a smaller bivalve far exceeds it as regards number. Univalves are not so abundant, and are usually of small size. I could find no distinct leaf-impressions, but I have no doubt that, if more time be given to the search than I could afford, the beds will yield to future collectors a rich harvest, both of shells and plants.

RED ISLAND.

From Patangata I crossed the hills to the coast at Mangakuri, noting in this line the southern extension of the Silver Peaks sandstone, described in the report of 1878 referred to above; but not till reaching the coast-line were Cretaceo-tertiary rocks met with. At the mouth of the Manawarakau River the latter appear as conglomerate bands and alternating beds of gritty sandstone and dark shales that to the north, on the mainland, are overlain by Tertiary clays followed by limestone, which continue to the mouth of Te Apiti Creek. Off the mouth of the Manawarakau, and extending some distance to the north, a reef of volcanic rocks forms a number of small islets less than or about a quarter of a mile from the shore, many boulders of which are cast up on the beach and can there be studied. This rock evidently is associated with strata belonging to the Cretaceo-tertiary series, and is in character the same as met with at Red Island, farther to the north. From Te Apiti the track to Waimarama passes inland, to avoid the difficulties of an almost impassable beach, but opposite Red Island passes within half a mile of the shore-line. This I again examined, and brought with me examples of the igneous rocks described in the report of the 1st March, 1875 (Geological Reports, 1874–76, p. 45). Since the date of that report deposits of manganese have been found on the mainland close to and nearly opposite Red Island, and on my last visit I found the ore occurring with and in the igneous rocks of Red Island itself.

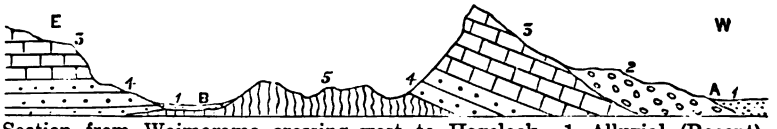
My last visit to Red Island was made for the purpose of obtaining specimens, because doubts have been expressed as to whether there are any igneous rocks at that place, and it has been stated that specimens brought thence show the presence of the jasperoid slates and Palæozoic sandstones of the "Rimutaka series." Professor Hutton seems to have doubts as to the presence of volcanic rocks associated with strata belonging to the Waipara system, along the east coast of the North Island. In one of his late contributions to the Geological Society of London, describing the eruptive rocks of the Waipara system, he says, "In the North Island volcanic rocks *said to be of this age* [the italics are mine] occur on the east coast of Wellington at Red Island, south of Cape Kidnappers, and, perhaps, near Castlepoint" (Quarterly Journal of Geological Society, 1885, p. 215). It was subsequently to his writing what is quoted above that he had at Napier an opportunity of examining hand-specimens collected at Red Island, and of concluding that these were sedimentary and not volcanic rocks. Specimens prepared for examination show that as regards the character of some of the Red Island rocks Professor Hutton was mistaken; and on my last visit I satisfied myself fully that there are no older rocks than those of the Waipara system at or anywhere in the neighbourhood of Red

Island, and I know of none within a distance of twenty-five miles.

Waimarama to the Tukituki Crossing, and Limestone Range at the Back (east) of Havelock.

For a distance of fully two miles to the north of Waimarama the coast is low and backed by an alluvial flat a mile or better in breadth. Farther to the north-east Tertiary beds of a dark-grey colour and sandy character form cliffs along the shore, and low reefs that are laid bare at low water for a considerable distance seaward. These beds surround an isolated outcrop of Cretaceo-tertiary or young Secondary rocks, that show a little south of where the track leaves the beach, from which point till close to the Tukituki River the hills are formed of a great thickness of the grey sandy beds that been described as underlying the Te Aute limestone at Takapau and Mount Vernon, and in the cliffs forming the east bank of the Tukituki above Patangata, &c. These beds give place to brownish sands in the higher part of the section, and on the east bank of the river are overlain by Te Aute limestone. Two or three miles east of the river they form hills, cover the whole country east to the coast, and they also extend with undiminished thickness north-east to Cape Kidnappers, and form the first mile and a half or two miles inside (west) of the cape. The limestones capping these beds at the Tukituki crossing have about 100ft. of hill-slope, and a narrow flat between their outcrop and the river. In the bed of the river Secondary rocks, as shaly hydraulic limestones full of calc-spar veins and containing concretions, appear at no great distance under the Tertiary limestones. Between these and the Tertiary limestone the great thickness of the intermediate beds cannot find place, and they either thin out with extreme rapidity, or a fault along the east side of the Tukituki Valley brings their upper beds in contact with the outcrop of the young Secondary rocks. It is possible, indeed it is probable, that such a fault exists; but, over and above the influence this may have had tending to bring the overlying limestone in contact with the young Secondary rocks, the sections farther to the north-west show that a very rapid thinning of the beds under the Te Aute limestones takes place.

In travelling from the river-crossing towards Havelock the Secondary rocks form a series of low hills on the left bank of the river, and continue to the eastern base of the limestone range behind Havelock. The lowest beds of the younger overlying series are not clearly seen; but the overlying Te Aute limestone occupies so much of the eastern slope of the range that not more than 150ft. to 200ft. of underlying sands can be present between it and the unconformably underlying series.



Section from Waimarama crossing west to Havelock. 1. Alluvial (Recent). 2. Pleistocene gravels (Patangata beds). 3. Te Aute limestone (older Pliocene). 4. Titiokura beds (Upper Miocene). 5. Cretaceo-tertiary (Mata River beds). A. Havelock. B. Tukituki River.

The coarse sandstone gravels following the Te Aute limestones form downs at the back of Havelock, and extend north-east, cross the Tukituki beyond the termination of the limestone range, and are continued through the hills on the right bank of the river till they appear in sea-cliffs of the Cape Kidnappers section. Farther to the west and north are the alluvial deposits of the Ahuriri Plain.

CAPE KIDNAPPERS SECTION.

From Cape Kidnappers westward, along the southern shore of Hawke's Bay, Tertiary beds, consisting of light- and dark-grey sandy and argillaceous beds, continue to the first point inside the cape, and are there overlain by the Te Aute limestone. The beds forming the latter, running as a low reef out to sea, have a dip to the westward. Superimposed on these, but unconformable to the limestones, a great thickness of conglomerates, sands, and clays succeeds, and these latter form high cliffs along the shore as far west as the mouth of the Maraetotara River, at which place they recede from the immediate shore-line, and form hills on the east bank of the Tukituki, which have already been alluded to. Although on the shore-line the exposed section exhibits a great thickness of strata, some 700ft. to 1,000ft., the beds do not extend far inland in a south and south-east direction. The beds are formed of heavy beds of sandstone conglomerates, grey sandy beds, and thick beds of plastic clay, containing lignite-bands. Beds of pumice-sand occur frequently in this section, and in the higher part the clays contain a few species of marine and estuarine shells. Leaves of dicotyledonous plants and ferns are found in the clays and in the pumice-sands, and at one or two places erect stumps of small trees with their roots imbedded in the under-clay, in conjunction with the shell-beds, testify the occurrence of slight depressions and upheavals of the land during the deposition of these beds.

As these beds follow the Te Aute limestone from the south shore of Hawke's Bay past Havelock to the south-east corner of the Ahuriri Plain, I formerly supposed them to succeed these limestones conformably, and to be the same as the Esk and Rangimapapa conglomerates and pumice-sands which underlie the Petane clays; but the past year's work has shown that similar gravels on the north bank of the Tutaekuri River, near Taradale, rest on a denuded surface of the Petane beds, and I therefore now

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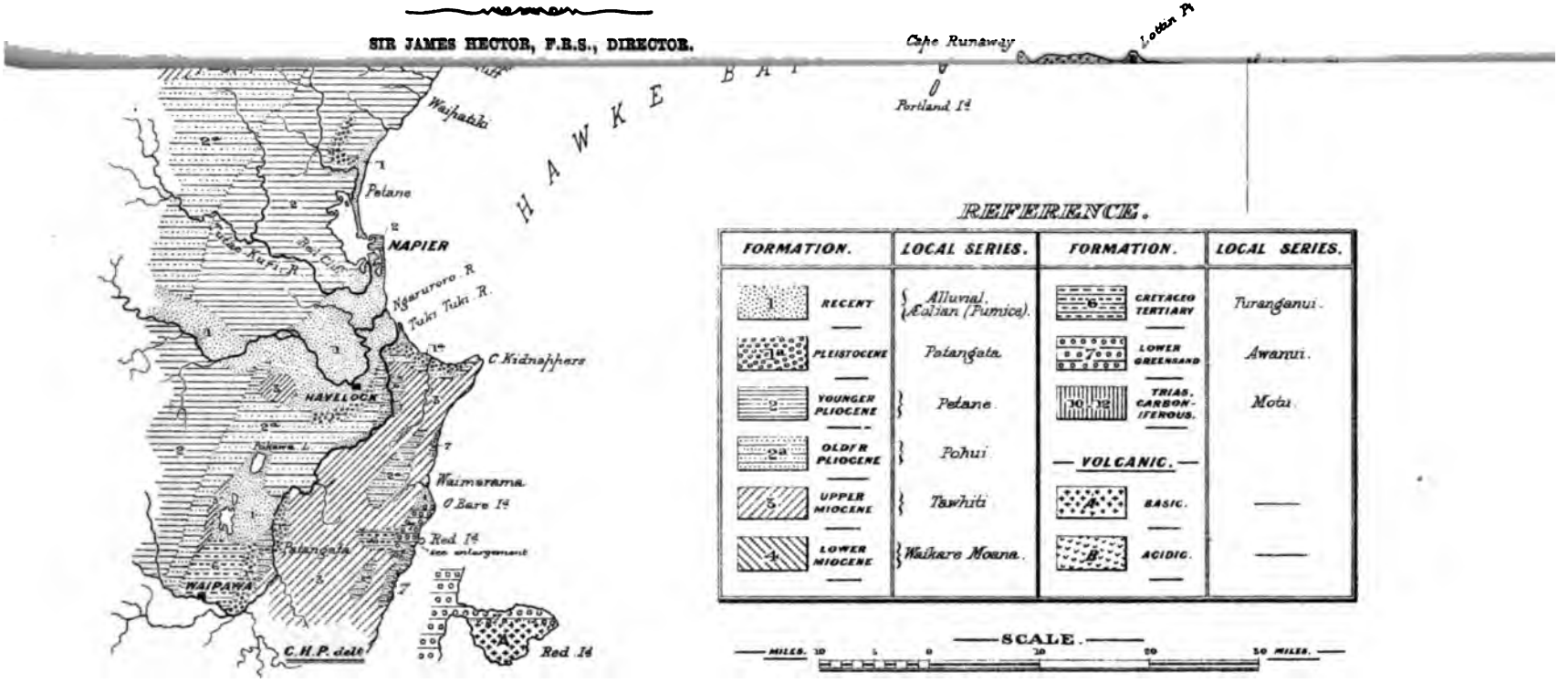


consider them to be of Pleistocene date, as they are necessarily considerably older than the alluvial deposits of the Ahuriri Plain.

Scinde Island.

I had a further opportunity of examining the beds in Scinde Island, and of making collections. The evidence collected confirms the view that all the beds in Scinde Island belong to one conformable sequence of strata, and the fossils from the lower calcareous strata make it impossible to refer these beds to a formation of greater age than the Pliocene period. I collected all or nearly all the species mentioned by Professor Hutton (Trans. N.Z. Inst., 1885, Vol. XVIII., p. 389); and, in addition, fourteen species not mentioned in the list referred to. Among the additions are two extinct species, *Cardium spatiosum* and a Perna, the same species as that found in the Petane beds at Matapiro, and at Castlepoint (see Trans. N.Z. Inst., 1885, Vol. XVIII., p. 365): the rest are all living species, so that the percentage of recent forms has not thus been decreased, but is raised to 71 per cent. There are also in the Napier Museum several additions to the fauna of the lower beds collected by Mr. Hamilton since Hutton's list was compiled, and these in no way tend to lessen the percentage of recent species from these beds, so that even in a greater degree than I anticipated my forecast of the results of more ample collections from these beds (Trans. N.Z. Inst., 1885, p. 372) has been realised. Scinde Island, being isolated from all Pliocene or older strata on the mainland, while as yet all are not agreed as to the age of the beds present, is unsuited to be taken as a typical and name locality of either the higher or the lower beds there exposed, and I have therefore compiled the classification of the beds dealt with in this report so as to avoid any difficulty that might arise from the use of the term "Napier beds;" but no such objection can apply to the term "Waipatiki beds," the Waipatiki River from its source to the sea lying within the area covered by the Petane limestone. Notwithstanding this change of the name, I refer all the beds in Scinde Island to the Waipatiki beds, which clearly overlie the Petane clays and sands; but, whatever the ultimate conclusion arrived at may be, there seems no likelihood that the lower limestone in Scinde Island will be referred to the "Pareora system" of Hutton, or be made to occupy the position in that which he has given to it and the Te Aute limestone.

North-east of the North Island.

I. Recent Formations.

Alluvial.—Deposits of this age and character are not very extensive on the east coast of this part of the North Island. In the northern district of Hawke's Bay a small area in the Lower Esk valley is occupied by an alluvial plain formed of gravels originally derived from the old Secondary and Palæozoic sand-

stones of the Kaweka and Ruahine Ranges, but in their present arrangement forming conglomerates at different horizons in the Pliocene strata of the adjoining district. In the Mohaka Valley there are beds of pumice-sands capping the terraces along both banks of the river, and appearing as the results of river-action. These sands are well seen at the Mohaka Bridge on the Napier–Taupo Road, and in the Waipunga Valley near Tarawera. Almost everywhere they contain branches and trunks of trees more or less altered, often in a condition resembling charcoal. In the Mohaka the pumice-sands are underlain by thick beds of sandstone gravels derived from the old rocks near the source of the river. Similar deposits are found on the banks of the Lower Mohaka, but either here, or in the valleys of the lesser rivers of northern Hawke's Bay, these require no special notice. In the Wairoa Valley, the only alluvial tract of any extent lies between Frasertown and the mouth of the river, where the deposits are of a loamy character. The plain inland of Poverty Bay as far as Ormond is of the same description, as is also an extent of flat land on the Lower Waikohu, before making junction with the Waipaoa. The Uawa (Tolago Bay) and Waiapu Valleys contain the only other extensive alluvial deposits on the East Coast. In the north-western part of the district, the Opotiki Plain and the low grounds of the Lower Whakatane and Rangitaiki are swampy and loamy alluviums, with pumice-sands and sandstone gravels on the higher grounds. In the middle Rangitaiki and Upper Whakatane valleys coarse sandstone shingle overspread by a loamy deposit prevails. At and south of Ahikereru the valley of the Whirinaki is covered with pumice-sands, partly sorted by river-action, and partly æolian deposits. The Upper Whakatane or Ruatahuna Plain is formed of sandstone gravels overlain by loamy soil. Its elevation is 900ft. to 1,000ft. above sea-level.

Æolian Pumice-deposits.—These are widely spread over the entire district. Over northern Hawke's Bay this superficial deposit is evidently derived in part from stratified beds of pumice-sand in the marine Pliocene strata of the district, but by far the greater amount seems to have been spread over the district in a manner of which the late outbursts at Tarawera and Rotomahana may be said to furnish explanation and proof.

Apart from the drift along the banks of the larger streams, this more general covering of pumice-sand was first noted by Mr. Cox, late Assistant Geologist, in a report on the country between Poverty Bay and Napier, describing them thus: "Post-tertiary: Under this head are . . . . certain deposits of pumice-sand and tufaceous beds which attain their greatest development inland, occurring only to a small extent along the coast ranges" (Geological Reports, 1874–76, p. 97). "Although these pumice-sands overlie the marls [of Cretaceo-tertiary age], they by no means obscure them, for the formation assumes the form of

the plateaux which have been deeply cut into by the rivers which take their course from the back-country to the sea" (*l.c.*, p. 98). Where they rest on Tertiary beds he describes the pumice-sands thus: "Soon after the Taupo Road leaves the bed of the Esk River, beds of tufa and pumice-sand, very similar to those occurring on the West Coast, in the neighbourhood of Raglan, appear and cover a considerable area of country, the soil of which appears to be very barren" (*ibid.*). Here Mr. Cox describes beds forming part of the fossiliferous Petane series of Pliocene date, and wrongly associates them with the drifting superficial pumice; but this recognition of "beds of tufa and pumice-sand" is an important fact, which some later observers have disregarded, or entirely overlooked. These excluded, it will be seen from the map accompanying Mr. Cox's report that the pumice-sands are confined to the area over which Lower Tertiary and Cretaceo-tertiary rocks are found.

Touching this same subject, Professor Hutton, writing in 1885, says: "I could detect no pumice in any of these beds [belonging to the Petane series], but it occurs in abundance at Titiokura Saddle, ... and at other places in beds lying unconformably on the Petane series, as has already been pointed out by Mr. Cox" (Trans. N.Z. Inst., Vol. XVIII., p. 342). Last year I ventured remarks respecting the manner in which this deposit has accumulated over northern Hawke's Bay, in which I considered it as the result of a wind-drift from the volcanic area to the west; but by far the most exhaustive and interesting account of the pumice-drifts covering this part of the North Island is given by Mr. Percy Smith, Assistant Surveyor-General, in a paper on "The Geology of the Northern Portion of Hawke's Bay" (Trans. N.Z. Inst., Vol. IX., p. 565). At page 572 of the volume referred to he says: "I have mentioned above the occurrence of pumice in this district. It is found nearly everywhere: on the river-terraces, the hillsides, and on the tops of the highest mountains, covering the surface with a deposit of sand, more or less deep, and in larger or smaller particles. During the course of the last five years it has been my duty to visit the tops of most of the higher mountains lying between Napier and Tongariro, and thence northward to the country under consideration, and in every case a deposit of pumice has been found, sometimes plainly showing, at others covered by vegetation. On Panikiri and neighbouring ranges round Waikare-moana it is found to a considerable thickness, whilst the lower lands along the lake are covered by it sometimes to a depth of 3ft. On the eastern side of the Maungaharuru Range it is very thickly deposited, being often, in the gullies, 6ft. to 8ft. thick. The extensive terraces of the Lower Mohaka River (which contain as large a quantity of level land as is to be found in the district) are thickly covered by it, thereby rendering them unfit for cultivation. Towards the east the deposit gradually thins out

until, approaching the vicinity of Poverty Bay, very little is seen. The only spots that are free from it are the lowest terraces of the rivers and the surface of the slips, and, as the country lying along the coast is the most subject to these slips as mentioned above, it is here that the pumice has in a great measure disappeared, thus allowing the grasses to spread. The general opinion appears to be that this pumice was ejected from Tongariro and the adjacent volcanoes, and was spread over the surface of the country by the wind; and there are certain considerations which favour this view, such, for instance, as finding the greatest thickness of the sand on the lee sides of the high ranges, where it would naturally accumulate; and also from the fact that the size of the particles appears to diminish as we recede from the supposed centre of distribution: but, at the same time, this will not account for all the facts. An examination of the sand seems to show that all the particles are waterworn or abraded, and that many of them are too large to be carried by an ordinary wind, being sometimes as large as walnuts, though the average size would be about an eighth of an inch in diameter. The only other hypothesis which would account for the presence of pumice over such an extent of country is that it has been carried into its present position by water. No doubt many of the extensive pumice-drifts of the North Island owe their origin to that cause, notably the pumice-plains of Kaingaroa, near Taupo, which in places are regularly stratified, and often contain the trunks of trees, lying in a horizontal position, converted into charcoal. There is a great deal of difference between the pumice-deposits of Taupo and the Waikato, and the inland portion of Taranaki and those of northern Hawke's Bay. The former are invariably level plains or depressions, which no doubt were at one time lakes. To my mind, a deposit of a light substance like pumice, which ordinarily floats on the surface of water, is only possible in enclosed sheets of water, which would not allow of its escape. If it once reached the open sea, it would be carried far and wide by the winds and currents. There is one thing, however, which should not be forgotten, and that is that the enclosed air, to which pumice owes its buoyancy, might under pressure be driven out, in which case, of course, it would become waterlogged and sink, and would then form regular aqueous deposits like sand or clay. That such deposits are sometimes met with I think every one must allow who has seen the Kaingaroa Plains, or the beds of coarse white sandstone near the Miranda Redoubt,—which is, I think, without doubt formed of coarse pumice-sand consolidated under pressure,—and the deep pumice strata found in the Tauranga District. . . . . Mr. J. C. Crawford, of Wellington, in his paper on 'The Old Lake System of New Zealand' (Trans. N.Z. Inst., Vol. VIII.), has touched upon this subject, and comes to the conclusion that the great central pumice-drifts are lake deposits. In this I entirely concur as far as relates to the country

described by Mr. Crawford, but I think that the lake theory cannot be applied in this district. The large extent and great height of the country over which the pumice is scattered precludes the idea that it is entirely due to the action of water, whilst the fact that the thickest deposit seems to be confined (in this district at least) to the northward of a line drawn in a true east direction from Ruapehu would add force to the argument that it was spread out by the prevailing western winds; and the waterworn appearance may be explicable on the supposition that it is due either to decomposition or to the attrition of the particles as they were ejected from the volcano. The amount of evidence, however, is not sufficient to come to a conclusion either way; nor are we justified in ascribing to Tongariro and its adjacent volcanoes the origin of the whole of this pumice until a thorough exploration of the mountainous Urewera country shall have proved that it did not emanate from some nearer source. That volcanic rocks exist somewhere in that direction is proved by the finding of volcanic pebbles in the bed of the Wairoa River, which must have come down the Hangarou, one of its main branches, and which has its source somewhere in the neighbourhood of Maungapohatu, a lofty mountain some twenty miles to the north-east of Waikaremoana."

In a report of later date ("The Eruption of Tarawera," by S. Percy Smith, Assistant Surveyor-General; Wellington, 1886), he says: "If a line be drawn from the summit of Ruapehu east to within fifteen miles of the coast, and thence north-easterly towards the East Cape till it strikes the road from Gisborne to Opotiki, and thence to the coast on the Bay of Plenty by that road, whilst another is made to extend from Ruapehu northerly to Matamata, and thence to the coast at Tauranga, we shall include an area of country of about 10,775 square miles, over the whole of which more or less pumice is found on the tops of the highest hills, with deeper deposits in the valleys. Nor is this pumice always in a fine state of division: on the hills inland of Hawke's Bay, and far to the north, the lumps are frequently the size of an orange; and at the eastern base of the mountains it has often accumulated in drifts, as if by the action of the wind blowing it over the ranges." Mr. Smith next describes the manner in which the original deposits of pumice have been modified so as to accumulate to a great thickness in valleys and the basins of former lakes, and points out that in one instance a level plain, the presumed bed of an old lake, "is so covered for ten or fifteen square miles with large blocks of pumice, so closely packed together that no horse can cross it" ("Eruption of Tarawera," p. 13); and, after describing the more earthy mud-like deposits of the Taupo zone west of the main axis as described by him, with reference to this, says: "Its great extension has hitherto prevented a proper understanding of the nature of this deposit; but,

if a minor explosion such as that of Rotomahana can cause such changes in the face of the country in six hours, what would not a few similar explosions on a somewhat larger scale effect over this larger district?" And on this subject he concludes thus: "From what has been said above it will readily be inferred that the covering of clays and pumice is, geologically speaking, of quite recent origin; it was subsequent to the changes that have taken place in the contour and depth of some of the lakes, as is proved by finding it spread in the same equal manner over the former bed of Rotorua" (*l.c.*, p. 14). With these remarks, so far as they relate to wind-drifted pumice in the district examined by me, in the main I agree; but may point out that in some parts the superficial pumice may be derived from Pleistocene and Tertiary strata, containing beds of pumice-sand, which I shall describe in another place.

With reference to the country north and north-west of Waikare-moana, the deposit is not thicker nor are the pieces of pumice larger than within the Hawke's Bay District; and, whatever rocks may be present in Maungapohatu, the pumice-deposits do not increase in depth or the pieces of pumice in size in that direction. Rhyolitic volcanic rocks were observed in the main source of the Whakatane, but nowhere on the track from Waikare-moana to Ahikereru were such rocks met with *in situ*, and nowhere in the vicinity of the main range, along the line of the Gisborne–Opotiki Road, were volcanic rocks met with. West of the Whakatane there may be overlap of the older pumice-drifts, and the results of the recent eruption at Tarawera and Rotomahana; but to the east of the main range there is between Poverty Bay and Tolago Bay an area over which no volcanic dust has fallen, and over which the loose pumice on the surface is directly derived from the marine strata of the formation underfoot, the pumice-beds in which have been laid down under water.

Raised Beaches.—Along the south coast of Napier and the shores of Hawke's Bay it is only at Waimarama where raised beaches containing marine shells are found. At this locality I have not examined the beds, but Mr. Hamilton tells me that shell-beds are found on the inland side of the low flat north of the station-house. The Ahuriri Plain, Petane Beach, the low sandy track southward of the mouth of the Wairoa and along the shore east to the mouth of the Nuhaka, are as much due to the heaping-up and fixing, by vegetation, of the drifting coast-sands as to an elevation of the land, though probably there may have been elevation to the amount of a few feet, the direct evidence of which is now obscured. The same may be said of the low isthmus connecting Mahia Peninsula with the mainland; but here a very slight depression would again make the peninsula an island. On the north shore of Mahia Peninsula there is a raised beach 5ft. to 7ft. above what is high-water mark at the present time. In this the

lowest bed is full of shells, from which over a hundred species of Mollusca, numerous Foraminifera, and other minute fossils were collected. On the terraced flat lands of the peninsula there are shingle-beds, evidently an old beach, at a height of 200ft. to 300ft. above the sea, which, whether belonging to this or the next series, may be noted here.

A few miles north of Poverty Bay there lies between the present high-water mark and the foot of the hills a narrow flat terraced, and evidently the terraces are raised beaches. At Tolago Bay the flat on which the township stands is evidently such, but there are no further evidences of the occurrence along the East Coast of raised beaches till reaching the mouth of the Waiapu, where the terraces on the north bank of the river may be regarded as such. Along the east shore of the Bay of Plenty there is at Whangaparaoa a low stony flat, from which the sea has receded in modern times.

At Te Kaha Point there is sea-worn shingle, 50ft. or 60ft. above present high water-mark, and a little farther to the south-west are deposits of sand and clay, in which are an abundance of marine shells (as casts) and impressions of tree-leaves, all of recent species. These latter deposits are 40ft. to 50ft. thick, and form cliffs of that height along the shore. They evidently formerly extended some distance seaward, and have suffered by marine denudation till but a remnant of what they formerly were remains as a narrow belt along the shore-line. At and in the vicinity of Opotiki I examined the coast-line for the occurrence of fossiliferous raised beaches, and was led to expect the occurrence of such on account of the reference to *Mactra rudis*, Hutton, said to have been obtained from a raised beach at Opotiki (Cat. Ter. Moll. and Echinodermata: Wellington, 1873, p. 19). From Opotiki to the mouth of the Rangitaiki the coast-line deposits are mostly of this age.

Ia. Pleistocene.—Patangata Series.

At Red Cliff, on the north bank of the Tutaekuri, near Taradale, and overlying the Petane limestone on both sides of the Lower Esk valley, are coarse sandstone gravels, with beds of pumice-sand which are referable to this series. These beds rise to 1,000ft. on the coast-range east of Kaiwaka station, and are found at sea-level on the shore of Napier Harbour, They cap the first limestone bluff four miles north of Petane Pa. and also the sea-cliffs from Tipahanui and the mouth of the Waikare to the Lower Mohaka. They may be present farther to the north-east — this part of the coast-line, *i.e.*, between the Mohaka and Wairoa Rivers, was not examined—but are not met with on the road between the Mohaka Ferry and Clyde. Such gravels, I am informed by Mr. H. Hill, of Napier, are found on the coast east of the mouth of the Wairoa; but, except that

the high-level gravels on Mahia Peninsula are regarded as belonging to this series, the beds do not appear to occur farther to the north-east till reaching Poverty Bay, where the gravels and sands with marine shells opposite Gisborne may belong to this series. To the north-east of Poverty Bay, as far as East Cape, the series is not represented along the coast, nor along the east shore of the Bay of Plenty till reaching within six miles of Opotiki; but from this point high-level gravels, pumice-sands, &c., are found near the coast-line, and for some distance inland, that are referable to this series.

II. Younger Pliocene.—Petane Series.

This series includes (*a*) Mahia beds, consisting of pumice-sands, sands, and clays, overlying the limestones on the west side of Mahia Peninsula. These limestones at Long Point abound in *Pecten triphooki*, and in physical character resemble the Te Aute limestone, but contain a percentage of recent shells equal to that of the Petane limestone, and are underlain by beds that must be regarded as typical Petane beds. The beds (*b*), Waipatiki beds, include an upper and a lower band of shelly limestone, parted by a series of sandy clays and pumice-sands. The lowest division of the Petane series—(*c*), the Kaiwaka beds—comprise the typical Petane clays and sands, and the pumice-sands, conglomerates, and brown sands of the Esk valley and Kaiwaka Creek, and the beds underlying, to the triple conglomerate of Rangimapapa Hill, on the road to Pohui.

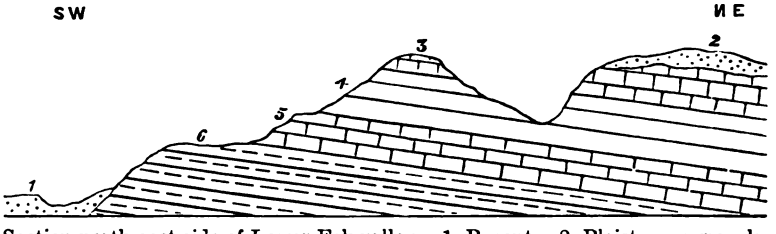
a. *Mahia Beds.*—These may occur to a considerable extent along the northern boundary of Hawke's Bay District between the Wairoa and Nuhaka Rivers, but were only examined closely on the road from Clyde to Mahia and on the south-west side of the southern part of Mahia Peninsula. The lower beds resting on the limestones of Long Point are very largely composed of pumice-sands, and are crowded with fossils belonging almost wholly to recent species. The higher beds are blue sandy clays, sometimes containing cement concretions. In these, fossils, though by no means scarce, are not so abundant as in the lower beds. A large collection of fossils was made from the lower beds a mile and a half south of Long Point, which, with the fossils from the Long Point limestone, were left at Kinikini for shipment. They have not yet been forwarded to Wellington.

Four miles west of the Nuhaka River the Long Point limestone appears on the coast-line, and there, as in Mahia Peninsula, is overlain by richly fossiliferous pumice-sands. The beds strike to N., and dip W. towards the Lower Wairoa valley, but in this direction the limestones do not again make their appearance, which they should do if the beds near the mouth of the Wairoa are the equivalents of the Kaiwaka beds; and the limestones

underlying the pumice-sands belong to the Waipatiki and not the Te Aute limestone.

In the Poverty Bay district sandy beds with fossils overlie the Ormond limestone, and perhaps should be referred to the beds under consideration, but too little work was done in that part of the district to determine this point.

b. *Waipatiki Beds.*—These near Petane and on the east side of the Esk valley are formed of—(1) Shelly limestone=Petane upper limestone; (2) pumice-sands and sandy clays, 140ft. thick; and (3) the lower Petane limestone. The limestones vary in thickness from 20ft. to 40ft., and elsewhere in the same district there are alternations of shelly limestones and sandy beds, that considerably increase the total thickness of the limestone members. In the hills between the Lower Esk valley and the infall of the river into Napier Harbour the two limestones and intermediate pumice-sands are nowhere very clearly shown, but in the hills to the north-east of the valley the three divisions are clearly marked, and are easily traceable by the eye along the sides of the range from opposite the schoolhouse for three miles up the valley, and as plainly are seen to overlie the sandy and marly clays of Petane belonging to the Kaiwaka beds. The following is a section seen as described half a mile above where the Napier–Taupo Road enters the valley :—



Section north-east side of Lower Esk valley. 1. Recent. 2. Pleistocene gravels, &c. 3. Petane upper limestone. 4. Sandy clays and pumice-sands. 5. Lower Petane limestone. 6. Petane clays belonging to the Kaiwaka beds.

These limestones reach the Tutaekuri Valley, between Taradale and Puketapu, and extend along the coast-range to Tipahanui, north of Petane; they form steep scarps to the westward, and along this attain an elevation of from 600ft. to 1,900ft., and where they terminate in Tipahanui form heights between 1,200ft. and 1,300ft. Along the coast they are found at sea-level at Petane, in Whakaari Peninsula, and along the sea-face of the range (impassable) for some distance to the north; but north of the Waipapa Stream the underlying clays reach greater and greater heights till in the sea-face of Tipahanui they form a cliff 1,200ft. in height.

North and north-east of Tipahanui these limestones are not met with *in situ* till passing the Wairoa; but there are large boulders of a shelly limestone found on the terraces immediately

south of the mouth of the Mohaka, and between the Mohaka and the Wairoa, in the valley of the Waihua River. Though north of the Mohaka the limestone no longer forms solid continuous beds, it at one place at least forms a cluster of large blocks that are evidently the wreck of a limestone band once capping the Kaiwaka beds at this place.

Four miles west of the Nuhaka River these beds appear on the coast-line, and are followed by the Mahia beds as already described. The beds here contain abundance of *Pecten triphooki*, but, of thirty-seven species of shells collected, about 80 per cent. are recent. The beds strike to N., and spread over a considerable extent of mountainous bush-clad country between the source of the Nuhaka and the Wairoa River. The same beds form the Long Point limestones on the west side of Mahia Peninsula, and probably the limestone appearing between the Waiau and Wairoa Rivers three miles west of Frasertown, on the road to Waikare-moana. In the Poverty Bay district, the Ormond limestones must be referred to this horizon, and also the beds that occur west of the Waipaoa River, where they appear on the Gisborne–Opotiki Boad. I do not know of any limestones referable to this horizon farther to the north or the north-east.

c. *Kaiwaka Beds.*—These embrace—(1) the Petane clay-marls and brown sands; (2) the pumice-sands and sandstone conglomerates of the Esk valley, below the junction of Kaiwaka Creek; and (3) sandy clays, brown sands, and conglomerates underlying, and the alternating pumiceous sands, shales, and conglomerates lying farther to the north-west.

The Petane clays, &c., are best known between the Lower Esk valley and Petane, and along the northern and western shores of Napier Harbour, where they have been closely examined and collected from by Mr. Hamilton. To the south-west they extend across the Tutaekuri into the Ngaruroro Valley, in which latter they form characteristic strata underlying the Petane limestones at Shrimpton's, at the east end of the Matapiro Plain. Farther to the south-west the clays overlying the Te Aute limestone along the eastern side of the Ruataniwha Plain may belong to these beds; but in this case the lower members of the Kaiwaka beds would have to be considered absent, as also would the Rangimapapa and the Pohui beds belonging to the Pohui series, which is improbable, seeing that all these are well developed within the Ngaruroro basin, at no great distance to the north. The clays follow the limestone scarp along the east side of the Esk valley, and this farther to the north-east to Tipahanui; and the contour of the range and the dip of the beds cause the outcrop to trend east to the seacliff, and south-south-west along the coast till the overlying limestone reaches sea-level.

On the road from Clyde to Waikare-moana these beds appear from under the limestones three miles north-west of the Wairoa at

Frasertown, and they form the highest beds in the syncline farther to the west. As blue or grey clay-marls they underlie the limestone on the west side of the Nuhaka Valley, and appear in Mahia Peninsula as grey sandy clays with large concretions and some thin beds of pumice-sands. In the Poverty Bay district, near Ormond and west of the Waipaoa, the clays are largely mixed with pumice-sands and sandy beds of a brown colour. Farther to the north-east and along the shore of the Bay of Plenty, at Whangaparaoa, any distinction between these beds and the next underlying is lost, and indeed it is questionable if any distinction can be made between these and the next lower outside that part of the district which lies betwixt the Ngaruroro and the Waikare River, south of the Mohaka.

This division of the Petane series is by some thought to be present in Scinde Island, overlying the lower of the two thick bands of limestone, this latter being referred to the Te Whaka–Te Aute limestone of the Pohui series. From these beds in the vicinity of Petane, and from the same beds along the shore and forming the islands of Napier Harbour near the infall of the Esk River, have been obtained most of the fossils of the Petane series as given by Professor Hutton in his paper on the "Wanganui system" (Trans. N.Z. Inst., 1885, Vol. XVIII., p. 336). Those mentioned as occurring at Matapiro come from the next underlying division of the Kaiwaka beds. In these clays crystals of hornblende and fragments of what appears to be pumice occur abundantly in the long cutting on the south side of the saddle behind Petane Schoolhouse, and in the western end of the island west of the mouth of the Esk is a bed of clear pumice-sand overlain by strata full of fossils. In this pumice-sand no shells were found, but towards its upper surface it is at places full of worm-burrows and annelid-trails.

Pumice-sands and Sandstone Conglomerates of the Esk Valley.—These beds are finely exposed along the east side of the Esk Valley from Wallace's to Kaiwaka Station, and for some distance farther to the north-east along the lower slopes of the range on the east side of the valley. Below the junction of Kaiwaka Creek they occupy some breadth of country on the west side of the valley, and are present in the hills behind Wallace's homestead. The low angle at which they dip and the increasing elevation of the land cause the outcrop of these beds to trend to the south-west, and they cross the Tutaekuri some distance above Puketapu; and south of this they are found throughout the hills as far as Kikowheru Creek, at the eastern end of the Matapiro Plain, and also on the south side of the Ngaruroro River.

To the north-east they may be traced as far as the northern slopes of Tipahanui, but beyond this lose their distinctive character, or have been denuded away, and their outcrop reaches the sea between the higher slopes of Tipahanui and the mouth of the Waikare

River, and necessarily returns south along the coast-line in the manner already described. In the other parts of the district to the north and north-east it has not been possible to distinguish this from the other divisions of the Kaiwaka beds, as the conglomerate band disappears in this direction, and pumice-sands are as abundant in the next underlying division as in this.

Lower Division.—These beds cover a great extent of country along the east coast of the district. In the Esk valley the higher beds consist of grey sandy clays with one or two bands of calcareous cement-stone occurring as rounded boulders, or as thin continuous bands. These harder bands are richly fossiliferous, but are not found outside the Esk watershed. Underneath these are brown sands, the lower beds of which show in the long cutting by which the Napier–Taupo Road leaves the bed of Kaiwaka Creek on the road to Pohui. This is fossiliferous at places, but not richly so. Underneath the brown sands is a band of sandstone conglomerate 8ft. or 10ft. thick, which shows in the banks of the creek above where the Taupo Road leaves its bed, and, under this, greyish sands and shelly beds formed almost wholly of a single species, *Artemis australis*. Underneath this are sandy pumiceous beds, clays, and bands of conglomerate, and at the base of the whole a thick band of conglomerate forming the second bold conglomerate scarp east and south-east of Puhoi. This I take as limiting downwards the Kaiwaka beds, but, as this is a purely arbitrary limitation of their range, the Rangimapapa beds of the Pohui series might very well be included with these Kaiwaka beds, there being no unconformity between the two. The Rangimapapa beds are not fossiliferous, and I therefore took the first strong conglomerate below the lowest fossiliferous horizon of the Kaiwaka beds as the division-line, and this under the supposition that when fossils are found in the Rangimapapa beds they are likely to better agree with those of the Pohui brown and grey sands overlying the calcareous beds of that series than with the higher of the Kaiwaka beds. South-west of the Esk Valley very little is known respecting these beds; but that they stretch in this direction across the Tutaekuri into the Ngaruroro Valley, and cross that about the middle of the Matapiro Plain, is undoubted. In this position a strong band of conglomerate seems to indicate the western limit of the Kaiwaka beds, the Rangimapapa beds, and Pohui beds: the latter equal the Kereru beds lying farther to the west, and resting on the Te Aute limestones, the equivalents of the Te Whaka beds. North-east of the Esk Valley this division of the Kaiwaka beds forms the grey sandy clay-marls at the mouth of the Mohaka, thence south to the Waikare River, and stretches along the coast to the Lower Wairoa, and has a large development in the northern part and along the eastern side of Mahia Peninsula. Over the whole of this part of the district the beds are distinguished by the

frequent occurrence of beds of pumice-sands and pieces of pumice up to 3in. dispersed in the clays, and smaller pieces often forming half the material of particular beds. These beds being the lowest in which pumice has with certainty been detected in the section from Petane to Pohui, where pumice has been found elsewhere in beds that might possibly be referred to a lower horizon, it has been thought sufficient to refer such beds to this horizon, and leave to future examinations the proof that pumice occurs in yet lower beds.

In this way, or by the presence of characteristic fossils, the occurrence of these beds has been proved in the Waipaoa Valley, eight miles north-west of Ormond, and thence north-east to the coast-line at Gable End Foreland, and along the coast to Tokomaru Bay; but the breadth of country inland occupied by these beds has not been determined, though this is roughly indicated by the presence of other beds underlying and outcropping to the west and north-west. North-east of Tokomaru Bay pumice is not met with in the beds forming Tawhiti, or in the clays forming the beds that constitute the hills on each side of the lower part of Waipiro Creek; but it appears in the higher beds of the section north of Akuakua, west of Te Wharepunga, and at the south end of Tupuroa Bay. Pumice again appears in the beds commencing north of the mouth of the Waiapu, and thence extending to East Cape, and for some distance west, but how far inland is not known. In all these cases the fossils found in the pumiceous beds are such as occur, or may be expected to occur, in the typical beds in the Esk Valley, along the banks of the Lower Mohaka, and near the mouth of the Wairoa River.

In the northern part of the district, along the east shore of the Bay of Plenty, strata rich in the same fossils as occur along the Lower Mohaka are found along the shore of Whangaparaoa Roads, and stretch inland to the south, perhaps not continuously, as far as the Raukokore River, where pumice-beds with marine fossils extend to the northern base of Kaikoura west and south-west of the Waikura Valley.

Large collections were made from these beds in the Esk Valley and at the mouth of the Mohaka, and of lesser bulk from the beds near the mouth of the Wairoa, from the same beds in Mahia Peninsula, and along the shore of Waihou Bay, south of Cape Runaway. Among the rarer or more remarkable fossils, *Sphenotrochus coronatus* was found at the mouths of the Mohaka and Wairoa Rivers, *Pecten zittelli* at the latter place and at Mahia Peninsula, and *Cucullæa alta* at Waihou Bay.

IIa. Older Pliocene.—Pohui Series.

This includes the triple sandstone conglomerate and other beds of Rangimapapa Hill and the Pohui grey and brown sands, some-

times called "papa," and also the shelly limestones of Te Whaka and the Maungaharuru Range, and, as a consequence, to this should be referred the Te Aute limestone in the southern part of the district. This inclusion of the calcareous strata of the Te Whaka is made on account of the high percentage of recent Mollusca found in the beds, which includes, with few exceptions, all the prominent shells found in the limestones. In previous reports, in common with Sir James Hector, Professor Hutton, and others, I referred the Te Aute limestone to the Upper Miocene; but, contrary to Professor Hutton's opinion, I always considered it as closing the deposits of that period. Of course it may be regarded as either the close or the beginning of a series of beds, and, disregarding the fact that it has been stated that the beds succeeding this limestone are unconformable thereto, it is in reality a matter of little consequence whether they are classified as Upper Miocene or as Lower Pliocene. During the present season I satisfied myself that there is no proof of unconformity between the Te Aute limestone and the Pliocene beds following along the east side of the Ruataniwha Plains, near Waipukurau, and a careful examination of the sections south-west and north-east of Pohui did not convince me that unconformity is to be seen there, nor after having examined the Upper Waikare valley could I adopt this view of the relation of the beds. In the East Cape district the beds that on the south-west side of Tokomaru Bay and at Akuakua may be referred to the horizon of the Te Whaka or Te Aute limestone lie conformably at the base of the Pliocene series, and this while it is admitted that they rest with seeming conformity on the underlying beds. Within the Waiapu watershed, on the Mata River, south of Hikurangi, the relation of the limestone to the beds overlying is the same; and along the east shore of the Bay of Plenty, from Whangaparaoa to the Waikura valley and Raukokore River, the limestones are at or close to the base of the Pliocene series, and any marked development of underlying beds that might be referred to the Miocene period is absent from this part of the district.

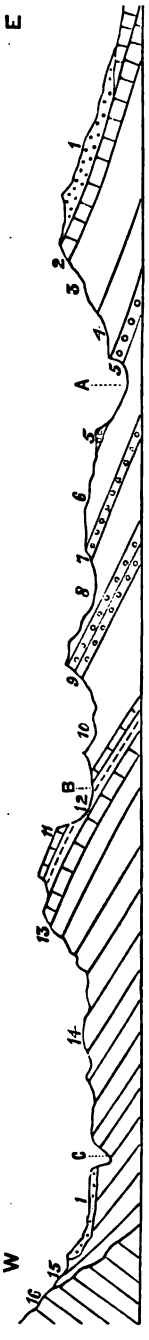
Last year I expressed the view that the limestone of Te Whaka, and as a consequence the Te Aute limestone, might prove of Pliocene age—a conclusion to which Mr. Park has been led by a study of the relations of the beds on the southern flanks of the Kaimanawa Range, and on the west coast of the North Island. For these reasons I have ventured to group the Te Whaka beds as part of the Pohui series of the classification adopted for this report and the accompanying map.

a. *Rangimapapa Beds.*—These are prominently developed in Rangimapapa Hill, on the Napier–Taupo Road, south-east of Pohui, and form a prominent feature in the country to the south-west, as far as the low grounds of the Tutaekuri valley. To the north-east they form a series of hills east of the Maungaharuru

Range, which continue as far as the Mohaka River, and somewhat farther north-east (though modified as regards the material forming the beds), into the Wairoa watershed. The conglomerates are easily traced to a great distance on account of the steep precipitous faces of their outcrop on the western side of the ridge, and the long low-angled slope of the eastern side. Numerous streams from the Maungaharuru Range cut across and deeply into these beds, and the sections thus show clearly the relation of the beds above and below them, and all the beds overlying are in continuous conformable sequence, as they also are downwards to the calcareous rocks of Te Whaka and the Maungaharuru Range. These beds have not been proved fossiliferous in the district south of the Mohaka. On the north bank fossils have been obtained from what should be the same beds. The collection forwarded to Mr. Hamilton, of Napier, consisted mostly of recent species.

b. *Pohui Beds.*—These are grey and brown sands that underlie the Rangimapapa conglomerates, and between the Tutaekuri and Wairoa River follow the Te Whaka, Maungaharuru, or other limestones occurring farther to the north-east in the same horizon, to be described under the head of "Te Whaka beds." Within the Wairoa watershed and to the north-east the Pohui beds appear to be represented by a blue papa clay. So far as examined within the Tutaekuri, Esk, and Waikare valleys these beds did not prove fossiliferous, and, excepting that they resemble the Kereru beds, and rest conformably on the Te Whaka limestones, there are no other proofs of their being their equivalents; but that they are is highly probable.

c. *Te Whaka Beds.*—These consist of a double band of shelly or coralline limestone, with sandy or argillaceous beds between. The uppermost bed is a shelly limestone that south-west of Pohui forms part of the Te Whaka Range to abreast of Pohui Lake. The eastern slope of this part of the range falls at a greater angle than the dip of the beds, and this upper limestone is thus exposed on both sides of the Pohui branch of Mangaone Stream for more than a mile to the south-west of the Taupo Road. This bed, with a dip E. at an angle of 20°, crops out on the western face of the line of hills east of Pohui Lake, and, continued to the north-east, passes to the eastward of Donnelly's station in the Esk valley, beyond which it again forms part of the higher mountain ranges—Maungaharuru Ranges. The section here given illustrates the succession of the different Tertiary beds from the west side of the Mohaka valley, near the Napier–Taupo Road, east to the sea:—



1. Pumice-sands and Pleistocene gravels. 2. Waipatiki beds = Petane Limestone. 3. Petane clays belonging to the Kaiwaka beds. 4. Pumice-sands under the Petane clays, &c. 5. Esk River conglomerate. 6. Kaiwaka Creek clays, brown sands, conglomerates, and fossiliferous pumiceous beds. 7. Sandstone conglomerates. 8. Sands and sandy shales. 9. Triple conglomerate of Rangimapapa Hill (7, 8, and 9 form the Rangimapapa beds). 10. Pohui papa grey and brown sands. 11. Upper limestone of Pohui Lake and Te Whaka. 12. Sandy clays. 13. Lower limestone, Te Whaka. 14. Beds, Titiokura Saddle to Mohaka Bridge (brown and grey sands and light-coloured sandy argillaceous beds). 15. Te Hauroto beds. 16. Old rocks forming the core of the Kiwi Range. A. Esk Valley. B. Pohui. C. Mohaka River. Beds 2 to 6 constitute the Petane series; 7 to 13, the Pohui series; 14, the Titiokura beds of the Tawhiti series; and 15, the Hauroto beds of the Waikare-moana series.

The middle beds consist of sands and sandy clays 150ft. to 200ft. thick, which are clearly exposed between the two bands of limestone on the higher part and north-west slope of the Whaka Range, and between Pohui and Titiokura Saddle, and are also seen farther to the north-east on the Maungaharuru Range. The lower limestone varies in thickness, being from 40ft. to 60ft. thick on the Whaka, and apparently much thicker on the range to the north-east. This limestone is continuous along the Maungaharuru Range to the Mohaka River, beyond which, till reaching the Waikare-Taheke Valley, it has not been clearly traced.

In the Waikare-Taheke it occurs as bands of coralline limestone, interbedded with brown and gritty sandstones. Here the beds contain none of the shells that are characteristic of this horizon in the vicinity of Pohui, at Te Aute, and along the eastern borders of the Ruataniwha Plain. A similar limestone occurs at the base of the Tertiary beds on the Waikohu River, four miles above its junction with the Waipaoa, in the Poverty Bay district; and shelly limestones containing *Pecten triphooki* occur in the Mata Valley east of Tokomaru Bay, which are referable to this horizon. Whether the calcareous rocks that on the south-west side of Tokomaru Bay contain pumice should be referred to this horizon is uncertain.

At Akuakua there are highly-pumiceous shelly beds overlying the grey sandy and blue marly beds of the coast-line thence to Te Wharepunga, which are of the same age and occur in the same horizon as the similar beds on the south-west of

Tokomaru Bay; but these are the only instances of the occurrence of Tertiary limestones or highly-calcareous rocks between Poverty Bay and East Cape.

The limestone between Kawakawa Roads and Hicks Bay I did not see, but it is probably the same as that which makes its appearance at Whangaparaoa. It covers a considerable area in the Waikura Valley, and is developed towards the base of the Tertiary series between the Waikura and the Raukokore River north of Kaikoura Peak, at the east end of the Kaikoura Range. From the lower limestone on Te Whaka a collection of thirty-five species of Mollusca was made, of which eight are extinct forms. In this there is therefore close upon 80 per cent. of recent species, a percentage so high that it is difficult to see how the beds can be separated from the Pliocene Petane and Pohui series.

Mr. Percy Smith and Professor Hutton both believe that these beds do not belong to the same series as the Pohui beds that overlie, and both have distinctly stated that the limestones are separated from the latter by an unconformity. I have already stated that I failed to observe this, and prefer to regard these Te Whaka beds as part of the Pohui series of the classification adopted for the purposes of this report. Hitherto these and the Te Aute limestone have been on quite other grounds regarded as closing the Upper Miocene sequence, a position which they yet occupy in the general classification of the New Zealand formations by the Director of the Geological Survey.

Tawhiti Series.—No unconformity separates this from the lower beds of the last, as seen in the section from the Titiokura saddle to the Mohaka crossing, nor as far as can be seen on the south-west side of Tokomaru Bay at Akuakua, or on the Motu River. It is possible, and even probable, that the Titiokura and the Tawhiti beds, which much resemble each other, are beds occupying the same horizon; but, on account of the very considerable distance between the two localities, they have been stated in the classification as distinct. The beds in the Mohaka Valley are poor in fossils, and the beds forming the higher part and middle slopes of Tawhiti are scarcely distinguishable from the Titiokura brown sandstones.

To these beds, it seems probable, should be referred the beds north-west of the coralline limestones in the Waikare-Taheke as far as the eastern shore of Waikare-moana Lake. These are gritty sandstones often calcareous and containing thin bands of coral limestone, which near the lake are parted by beds of sandy clay-marls that contain a number of small fossils, some of which are found on the south-east bank of the river at the Mohaka crossing on the Napier–Taupo Road (Pteropods), and some of which (as *Nerea kirki*) indicate a greater age for these beds. In any case, the beds conformably underlie the Whaka and Maungaharuru limestones, and the higher calcareous beds under the

Petane series in the section from the Wairoa River to Waikare-moana Lake.

The Tawhiti beds, as seen in the block of hills between Tokomaru Bay and Waipiro (Open Bay), are for the most part soft brown sandstones with few or no fossils. These on the north-east side of Tokomaru Bay rest on dark marly clays, which appear to be absent at the south head and along the south side of Open Bay, but appear on each side of the lower part of Waipiro Creek, and on the coast between Akuakua and Te Wharepunga. These Tawhiti beds were in 1874 referred to by Sir James Hector as Lower Tertiary in the Progress Report for that year; and by Professor Hutton are considered as belonging to the Pareora system (Journal of Geological Society, 1885, p. 209), and they are probably not misplaced here.

IV. Lower Miocene.—Waikare-moana Series.

Under the last-described beds grey clays are seen along some parts of the eastern shore of Waikare-moana Lake, and on the north-west side of the lake these are underlain by gritty sandstones, which, dipping to the eastward, continue to the head of the northern arm of the lake, and are there underlain by dark crumbling mudstones. Beyond this point to the north and north-west there is a great thickness of beds of the same character. These form the main watershed between the streams flowing east and those flowing north-west to form the Whakatane River, and beyond the height of land continue for six or seven miles along the track leading into the main valley of the Whakatane. Towards the base of the series in this part of the district the rocks are mostly brown sandstones without fossils. At the head of the north arm of Waikare-moana Lake a few fossils were found, among which I identified *Siphonalia nodosa*, and a Lima which, though of small size, resembled *Lima colorata*, Hutton. Close under the main range on its south-east side, where the rocks are mainly soft sandstones alternating with beds of crumbling sandy clays, shells and corals were found in one or two beds of a more calcareous character. The corals seemed to be the same as those found between the beds of gritty sandstone east of Waikare-moana Lake, and the only shell that could with any probability be be determined seemed to be a large species of Cytherea, perhaps *C. enysi*.

The extension of these beds to the south-west reaches into the Waipunga Valley, near Tarawera, and into the Mohaka Valley at the north-eastern end of the Maungaharuru Range, where the Hauroto beds are their probable equivalents.

In the East Cape district, the Akuakua and Ihungia beds are referred to the same series, as lying at the base of the Tertiary series, and there being no direct proofs in support of their belonging to an older series of Tertiary deposits. The Akuakua beds were

formerly regarded as belonging to the Cretaceo-tertiary formation; but the same beds at the mouth of Waipiro Creek rest unconformably on the Secondary rocks, and in the Ihungia rolled pebbles containing fragments of Inoceramus are found in the gravels that form a considerable part of the series in that part of the district. Beds the equivalents of one or other division of this series occur at Kawakawa and Hicks Bay, but I had no opportunity of examining or collecting from the beds there.

Hereheretau Beds.—Little more than what has already been noted can be said respecting these beds, excepting that their extension to the north-east appears to be limited to the district south-west of the Waikohu watershed, as no rocks referable to this series were met with in the section from Ormond to the Motu River along the Gisborne–Opotiki Road. The immense thickness of the series north-west of Waikare-moana led me to suspect that the lower part might be referable to the Cretaceo-tertiary series; but, the few facts ascertained respecting the beds north-west of the lake not bearing out this assumption, but rather proving that the beds are not older than the Hauroto beds, I have been compelled to regard them as the equivalents of these latter.

Hauroto Beds.—These were collected from and reported on last year. A further and more extensive collection of fossils was made this season from the beds outcropping in the creeks immediately west of the Mohaka Bridge, and the boundary-line between these and the Titiokura beds was traced along the north-west slope of the Maungaharuru Range from above the Waipunga junction north-east in the manner shown on the map. These beds were noted as strata deeply involved among rocks of old Secondary or Palæozoic age showing in the Waipunga Gorge east of Tarawera, and at the foot of the steep ascent from the Waipunga Valley to Hauroto Pa. The exposure of younger rocks in the river-bed is at first not more than 2 to 3 chains wide, and the beds are standing at very high angles or vertical. To the north the breadth of their exposure increases, and it is highly probable that this is connected with the area of Tertiary rocks south-west of Waikare-moana. In the Waipunga Valley these beds are crowded with a species of Struthiolaria (*S. tuberculata ?*), and the same shell occurs in great abundance in a brown sandstone on the north-west slope of the Maungaharuru Range, where the beds cross from the Hauroto Pa to the right bank of the Mohaka.

b. *Akuakua Beds.*—A further collection was made from these beds, and the similarity of the beds to those on the north-east side of Tokomaru Bay and some parts of the Ihungia beds was noted. The fossils are not in the best state of preservation, and consist of a few molluscs — Venus, Leda, and Pecten,—with numerous small corals, Bryozoa, and Foraminifera.

c. *Ihungia Beds.*—The same beds have a large development from

Tokomaru Bay north-west to Puketiti and west to the Mata River, and consist of marly and sandy clays, sands, and conglomerates. The finest sections of these beds are seen in the banks of the Ihungia near Puketiti, and for the next four miles along the course of the stream to the north. The remarkable feature of these beds is the contained conglomerates, which form thick beds at frequent intervals, and are to a very large extent formed of crystalline rocks, none of which is known *in sitû* in this part of the North Island. These in their physical aspect and mineral constituents resemble the crystalline hornblendic rocks of the west coast of Otago, in the South Island; and in the Ihungia and Mata Rivers the conglomerates formed of these contain subangular blocks up to, and in some cases exceeding, 2ft. in diameter. There are no traces of such rocks among the older sedimentary beds that form the mountains east of the Bay of Plenty, except in the vicinity of Whangaparaoa, where a grey diorite forms a considerable proportion of the shingle on the beach. Possibly such rocks may be found *in sitû* between Cape Runaway and Lottin Point and in the country to the south—a part of the district I did not examine. Mr. Cox describes the rocks on the coast-line between Okare and Matakawa Point as "trachytes and trachyte agglomerate," which he thinks must be at least of Upper Eocene age (Geological Reports, 1876–77, pp. 112, 113).

VI. Cretaceo-tertiary.—Turanganui Series.

a. *Waikohu Beds.*— Somewhere between the headwaters of the Wairoa and Waikohu Rivers Cretaceo-tertiary rocks begin to form the main range of this part of the North Island. On the road from Gisborne to Opotiki Cretaceo-tertiary beds appear about four to five miles west of the junction of the Waikohu with the Waipaoa, and continue without interruption to the point where the Opotiki Road reaches the main valley of the Motu River. Along the main range the higher beds form a flat syncline, and consist of alternations of sandy or marly calcareous rocks and greensands, with occasional harder bands of indurated shelly limestone. No distinct fossils could be obtained from these harder bands of limestone. In the more marly limestone, which at many places closely resembles the Cobden limestone of the west coast of the South Island, there is a frequent occurrence of the large circular radiately-marked fucoid common to the Amuri and Cobden limestones, and sometimes abundant in the Grey-marls of the South Island. On the western slope of the range the beds are soft argillaceous sandstones of very considerable thickness, dipping at low angles to S.E. Everywhere there is a remarkable sameness in the characters of these rocks, and throughout the series there is an absence of conglomerates. On the east side of the range the lower beds of the more calcareous rocks often resemble the hydraulic limestones of the northern part of the North

Island; and from beneath these appear sandstones of a more gritty character, with beds of indurated greensandstone that, dipping more to S., form an anticline between the forest-clad country of the main range and the commencement of the Tertiary rocks to the south-east. The last of these rocks seen show as dark marls containing thin veins of calc-spar and numerous irregular cement-concretions, corresponding with what may be seen near the entrance to the Big Bush. To the south-west of the Gisborne–Opotiki Road these beds extend some distance, but how far is not known. To the north-east for some considerable distance as little is known of them, but they are present along the west side of the Mata Valley ten miles south-west of Hikurangi, and are probably continuous thence into the Waikohu Valley.

b. *Turanganui Beds.*—These are probably the same as the lower part of the last, but separated by a considerable distance, and, the Turanganui beds not being closed by the limestones and calcareous rocks of the series farther to the north-west, they may for the present be regarded as distinct. Marly clays form the highest of these beds, and these are seen to have a very considerable thickness on the north-east side of Poverty Bay. As dark-coloured soft sandstones and clays the same beds are found on the coast-line as far as Whangara, and there are underlain by indurated greensandstone, which may correspond with the greensandstone of the Waikohu River, or with another horizon of greensands under the Amuri limestone, but in the latter case the Mata River beds (Amuri limestone) would have to be considered absent, or represented by the lower part of the Turanganui beds. The dip of the beds near Gisborne is to N.W. at moderate angles, and on the coast south-west of Whangara to S. at high angles. Fossils are not plentiful in these beds anywhere, but a few species have been obtained from the north-east side of Poverty Bay.

c. *Mata River Beds.*—These are limestones corresponding in their chemical composition, physical characters, and geological position with the Amuri limestone. They are seen at but three places—viz., on the Mata River, twelve miles south of Hikurangi; a little to the south of the hot-springs at Waipiro; and between Te Wharepunga and Tuparoa. Calcareous marls occupying the same position are seen on the coast a little south of Awanui, but these do not take on the true characters of Amuri limestone. Nowhere are the beds fossiliferous, and, excepting that at places there is contortion of the beds to a great degree, and the limestones are associated with black tufaceous sandy beds and thick beds of crystalline conglomerate, the chief interest connected with them is that they are conformably overlain by the Waikohu beds, and at the same time are seen to belong to the series of undoubted Secondary rocks that underlie. Their evident relation to the latter is to be seen near the coast-line, while on the Mata River the limestone, which as much resembles Amuri limestone in its

physical characteristics, is seen to be followed by beds that are properly called "grey-marls," and rest upon others that contain dicotyledonous leaves, and these in turn on the Inoceramus beds and black shales of Awanui.

d. *Whareriki Beds.*—These beds have a considerable development between Waipiro and the mouth of the Waiapu, and extend to the westward as far as the main watershed between the East Coast and the Bay of Plenty. The beds consist of greensands, grey or blue marly strata with concretions, and a black bituminous mud or shale as the lowest member. The greensands can be seen on the south side of Open Bay, and along the stream that runs to the south of the hot-spring east to Open Bay. Puketiti is mainly formed of indurated greensandstone belonging to this horizon. From Puketiti the beds strike W. or W.N.W. across the Ihungia Valley to the Mata River and the eastern slopes of the main range south-west of Hikurangi, and on the northern side of the anticline appear in Te Wharepunga Creek and the hills to the north-west. Near Awanui the same beds are exposed on the coast-line and in the hills between the coast and alluvial flats of the Waiapu Valley. Greensands and fine-grained breccia-grits, with sandstones and marly shales, are here the highest beds. In the sandstones and concretionary boulders in these beds fossils often occur, and from boulders washed out of these or the next underlying beds a considerable collection of fossil Mollusca was made. This includes species of Belemnites, Ammonites, Ancyloceras, Baculites, Inoceramus, and about twenty other species less indicative of the Secondary age of the beds. At Awanui the middle division of these beds is a blue marl with calcareous concretions and numerous small concretions of barytes. Fossils in this are not so abundant as in the higher beds, and are principally Inoceramus, for the most part in a fragmentary condition.

Underlying these, the lowest beds of this series are the black shales that show on the coast at and a little to the north of Awanui, and for some short distance inland. The same beds appear on the east side of the Waiapu Valley on the road from Awanui to Rotokoutuku, and on this the north-east side of the anticline in the Tapuwaeroa Valley, and have been passed through in the last and deepest boring for oil made by the Southern Cross Company. On the southern side of the anticline this same black shale is traceable from west of the Mata River and south of Hikurangi to the coast at Waipiro, and should again appear at the back of Akuakua. This black shale contains flattened tubular bodies, which sometimes occur in great abundance; but other fossils are only plentiful on the coast-line near Awanui, where they are found both in the black shale and in hard concretions which it sometimes contains. The fossils have a more Tertiary aspect than those of the overlying beds, and represent the genera Cerithium, Natica, Dentalium, Mactra, Dosinia, and Solenella. A remarkable

shell, probably allied to Unio, is found in these beds and the overlying beds as well. It is often of large size, in some instances reaching a length of 6in. or 7in. Several of the fossils found in this shale are the same as, or closely resemble, species found in the first fossiliferous horizon overlying the coal on the east coast of the South Island; and, if on closer examination of the specimens this determination is verified, the presence of undoubtedly Secondary forms in the overlying beds at Awanui will further tend to show that beds in the South Island sometimes called Tertiary are of Cretaceo-tertiary or young Secondary ages.

VII. Lower Greensands.—Awanui Series.

This series corresponds, in its higher beds at least, with the lower greensand, Amuri series, at Amuri Bluff. The lower division, Taitai beds, are possibly yet lower in the scale than any beds in the Amuri section or along the east coast of the North Island, and the character of the rocks and the few fossils that have been obtained resemble more the higher of the Middle Secondary formations than the rocks and fossils of the Amuri series, but so far as seen in the East Cape district these are perfectly conformable to the young Secondary and Cretaceo-tertiary beds of that district. The chief development of this series shows on the coast-line between the south side of Open Bay and the mouth of the Waiapu River, and extends west to the principal watershed between the Waiapu Valley and the streams flowing into the Bay of Plenty. A lesser area, the exact limits of which are not known, lies on the east side of the Waipaoa Valley, surrounding the South Pacific lease. Another small area of these rocks occurs on the coast of the mainland between the mouth of the Nuhaka River, Hawke's Bay, and some six or seven miles north of Mahia Peninsula; and yet another on the shore of the Bay of Plenty, between Waihou Bay and the mouth of the Raukokore River; and, judging from the shingle in the bed of the stream, there seems to be yet another in the valley of the Whangaparaoa River, but this last may be connected with the larger area on the East Coast.

a. *Waipiro Beds.* — These consist of grey thin-bedded sandstones, often highly calcareous, interbedded with dark-coloured shales. The beds are at most places much disturbed, and, resting at all angles, are at many places highly contorted. On the coast at Waipiro they form an anticline, and from Tuparoa to the end of the sandy beach north of Riparua they appear as highly disturbed strata, but on the whole have an anticlinal arrangement. Between Awanui and the mouth of the Waiapu they form an anticline, and nearer the river a syncline, the beds forming the syncline and on the south side of the anticline being overlain by the bituminous shales already described.

The general arrangement of the beds on the coast-line from Tawhiti to the East Cape is shown in Sec. II. (Tokomaru to

Waiapu), Geological Reports, 1873–74: Progress Report by Dr. Hector, p. xiv. West of the Waiapu River the section from the south slopes of Hikurangi to the north-east side of the Tupuwaeroa Valley is less complicated than on the coast-line, and is represented below:—

Section from Hikurangi across Tupuwaeroa Valley and Rotokautuku Block. 1. Grey marly beds. 2. Black shales. 3. Contorted grey sandstone. 4. Dark shales and sandstones, crushed and contorted. 5. Grey and green flaggy and thick-bedded sandstones, alternating with green sandy shales.

b. *Taitai and Hikurangi Beds.*—Beds Nos. 4 and 5 of the above section form the Taitai and Hikurangi beds, which form the whole of the eastern end of Hikurangi, Aorangi, and all but the north-east lower slopes of Taitai. The higher beds consist of dark drossy shales and dark-grey sandstones, the former often containing concretionary boulders that assume a reddish-brown colour when exposed to the atmosphere. From them a few fossils were obtained, of which one is identical with a form common in the Jurassic beds of Kawhia Harbour; and, as they lie below the grey sandstones of Rotokautuku, Awanui, Waipiro, &c., they, with the underlying sandstones and shales, may be considered as the lowest ascertained beds of the Lower-greensand formation in New Zealand. The lower beds have a great thickness, and at many places are crowded with broken plants, but never in such a state of preservation as to indicate the nature of the flora thus entombed. At one particular horizon a bed of sandstone is crowded with Inoceramus shells—a large flat shell having numerous concentric plications, and in this respect resembling a form found in the Secondary rocks of the East Coast of Wellington.

X.–XII. Trias to Carboniferous.—Motu Series.

Te Kaha beds.—These rocks in the southern part of the district are evidently the same as, and a continuation of, the beds forming the Kaweka Range. North-east of Hauroto Pa they form a mountain-range on the west side of the Mohaka Valley, which more to the north-east appears to be surrounded by mountains formed of Tertiary strata. This series forms the mountains surrounding the source of the Whakatane River, and thence in a north-east direction are (so far as known) continuous, till they run out on the east shore of the Bay of Plenty. West of the Upper Whakatane to the east side of the Rangitaiki Valley these rocks form mountainous country, except near Ahikereru and for some distance to the south-west, where rhyolitic flows and pumice-deposits are present in the low grounds, the range to the west being formed of old sedimentary rocks.

In the middle Mohaka and Waipunga valleys, besides the grey sandstones and crumbling slaty shales that constitute the bulk of this formation, there are calcareous diabasic rocks of a red and green colour, with bands of grey chert and veins of calc-spar. In the Upper Wakatane jasperoid slates appear in the river-bed; and among the mountains to the west beds of compact white limestone occur, boulders of which were observed in the bed of Okahu Stream, five miles east of Ahikereru. At the Motu Bridge, on the Gisborne–Opotiki Road, the rocks are thick-bedded gritty sandstones, and grey in colour, beneath which dark-grey sandstones and black slaty shales alternate rapidly. At Te Kaha, on the shore of the Bay of Plenty, the mass of the strata is grey sandstones and dark shales, with nodules of blue limestone and thin veins of calc-spar, but near the extremity of the promontory there are bands of red and grey cherts and veins of chertose quartz yielding small quantities of copper.

Volcanic Rocks.

Basic Rocks.—The only rocks of this character are found at Red Island, on the coast south of Cape Kidnappers. These have already been noticed.

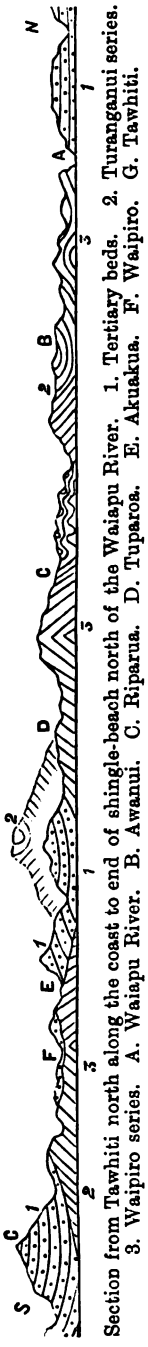
Acidic Rocks.—Apart from the pumice-drifts spread over the greater part of the district, solid flows of trachyte rocks are found in the Waipunga Valley; at Stony Creek, near Tarawera; and forming the higher part of Pukerenui Hill, between Tarawera and Runanga, near which these rocks begin as a continuous sheet, and spread over a large extent of the central part of the North Island. From the vicinity of Runanga the same rocks extend north-east along the valley of Whirinaki Stream to Ahikereru, and appear at one time to have formed a plateau to the eastward as far as the source of the Whakatane River, out of which the mountains of that part of the district have been sculptured. Showing this, boulders of trachyte are not uncommon in the bed of the Whakatane some ten miles from its source, and some of the mountains in that direction appear as though capped by a thick bed of light-coloured rock, like which, except trachyte boulders, there are no rocks represented in the shingle of the river-bed.

Concluding Remarks.

The examinations described in the foregoing report lead to the following conclusions:—

1. That the heavy gravel deposits on the south shore of Hawke's Bay between Cape Kidnappers and the mouth of the Tukituki are younger than the beds forming Scinde Island, and of greater age than the deposits forming the Ahuriri Plain, and are, as a consequence, of Post-pliocene age:

2. That all the marine beds seen in Scinde Island are of



Section from Tawhiti north along the coast to end of shingle-beach north of the Waiapu River. 1. Tertiary beds. 2. Turanganui series. 3. Waipiro series. A. Waiapu River. B. Awanui. C. Riparua. D. Tuparos. E. Akuakua. F. Waipiro. G. Tawhiti.

Pliocene age, and are represented in the section from Te Whaka east to the sea at Whakaari Peninsula, and that probably none of the Scinde Island beds are older than the Petane clays:

3. That all the beds along the course of the Esk River from Petane to Titiokura saddle are conformable to each other, and that there is no distinct evidence of unconformity in this line of section till reaching the base of the Tertiary sequence, on the north side of the Mohaka valley, and that everywhere the evidence indicates a continuous conformable sequence of the Tertiary beds on the east coast of the Island north-east of Napier:

4. That the beds west and north of Waikaremoana Lake for some distance towards the main watershed are undoubtedly Tertiary, while it is possible that the base of the younger rocks on the north-west side of the range may be of Cretaceo-tertiary age (proofs being wanting, the whole has been treated as belonging to the Tertiary period):

5. That pumice, as sands or dispersed fragments of variable size, occurs in all the beds overlying the Rangimapapa beds and their equivalents to the north-east; but, if the limestones of Long Point, in Mahia Peninsula, are of the age of the Te Whaka and Te Aute limestones, pumice must be considered as occurring in the underlying beds as low as the equivalents of those at the Mohaka crossing on the Napier–Taupo Road:

6. That in the Waiapu and Upper Waipaoa valleys the Cretaceous rocks representing the Amuri limestone are followed by a great thickness of marly strata, referable to the Grey-marls, and that the series is closed by rocks resembling in character the Cobden limestone on the west coast of the South Island:

7. That the bituminous shale of Awanui, Rotokautuku, and Waipiro overlies the grey sandstones in which boring for oil has been carried on in this district, and that if this or an overlying storage-bed is being sought for there can be no doubt that it has long since been passed through in the last bore put down by the Southern Cross Company:

8. That, while in almost all cases the gas-springs and indications of oil appear at the surface in the sandstones constituting the highest beds of the Awanui series, the actual source of the oil may

be at a considerable depth below these, and probably is referable to the greensandstones and sandy green shales forming the Hikurangi beds, and there are grounds for the opinion that these cannot be reached on the Southern Cross lease by a bore that is less than 3,000ft. in depth.

The relative vertical position and thickness of the different beds that would have to be passed through are shown in this report, in the section on page 216; and the position of the black shales relative to the Waipiro beds is shown in the section on page 218, which, except in minor details, is practically the same as that given in the Director's Progress Report for the year 1874 (Geological Reports, 1873–74, p. xvi., Sec. II.).

KAIPARA AND WADE DISTRICTS, AUCKLAND.

REPORT BY JAMES PARK.

NARRATIVE.

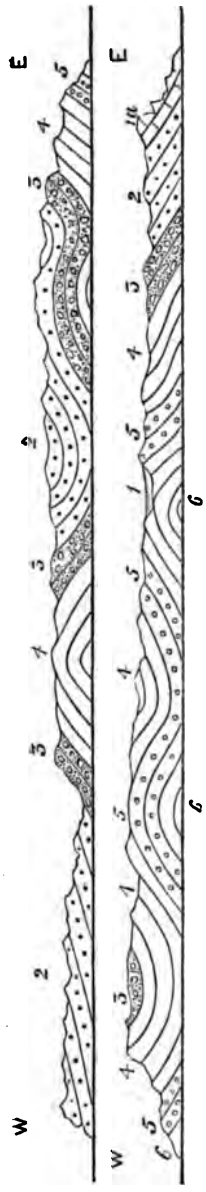
16th September, 1887.

I HAVE the honour to report that, in accordance with your instructions, I left for Auckland on the 13th May, arriving there on the 14th. On the 16th I proceeded to Batley, which I reached on the forenoon of the following day. During the remainder of the day I examined the section on the beach between Batley and the Native settlement two miles higher up the Otamatea; and on the 18th the section from Komiti Point to Pahi, at the same time revisiting the south side of Komiti. On the 19th I examined the south side of the Pahi arm from Jackson's to the Gibraltar Rocks, near Captain Colbeck's house; and on the 20th and 21st I visited a number of localities in the vicinity of Paparoa, with a view of determining the extent of the probable coal area there. In the evening of the 21st I proceeded to Hakaru, and the following day examined the section through the gorge to Bream Tail. On the 23rd I returned to Auckland, and the next day visited Motutapu Island, where I made a large collection of fossils. From the 25th to the 30th I was engaged examining the coast sections near Lake Takapuna, Wade, Okura, and Orewa. On the 31st I started for Wellington, which I reached next day.

REPORT.—KAIPARA DISTRICT.

Sections at Batley.—The hydraulic limestone is largely developed at Batley, forming the whole of the peninsula between the Arapaoa and Otamatea arms. It is much shattered and jointed, and everywhere intersected by numerous calc-spar veins. About 50ft. from its base it is interbedded with a bed of light-coloured sandstone, spotted with grains of glauconite.

In the section from Batley to the Native settlement two miles farther up the Otamatea it is underlain, apparently unconformably, by thin-bedded siliceous shales alternating with softer blue clays, which contain large irregular masses of indurated greensandstone and septaria. In the centre of one of the latter I found several fragments of a large Inoceramus. Bands of black ferruginous sandstone and greenish greasy clays are often associated with the septaria beds. In many cases the septaria themselves are covered with a thin layer of cone-in-cone limestone.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E
1. Recent sands and gravels. 1a. Orbitolite bed. 2. Yellowish tufas and breccias, spotted with a white vesicular rock; contain beds of impure coal or lignite and masses of silicified timber. 3. Coarse volcanic breccia with large rounded masses of solid lava. 4. Coarse gritty sandstone with ironstone bands. 5. Coarse sulphurous sandstones with layers of white concretions, interbedded with two mullocky dirt-beds with *Crassatella attenuata* and other large bivalves near base. 6. Marly greensand with *Pecten zittelli* and numerous other fossils.

Komiti Point to Pahi.—The annexed two sketches represent the sequence and disposition of the beds along the south face of Komiti for a distance of two miles past the point opposite Batley.

During my visit to the Kaipara in March, 1885, I examined the south face of Komiti Peninsula, but, on account of the unusually stormy weather which prevailed at that time, I was unable to devote as much attention to the study of the important sections there as could have been desired. This year I again visited Komiti, and, under more favourable circumstances, carefully revised my former work; and, as a result of the additional information which I then obtained, I am now in a position to make several important alterations in the sequence as previously determined.

The trachy-dolerite breccias and tufas which were supposed to belong to the Manukau breccias are found now to belong to the Komiti marine series, which on the Wairoa side of the peninsula are interbedded with solid lava-flows.

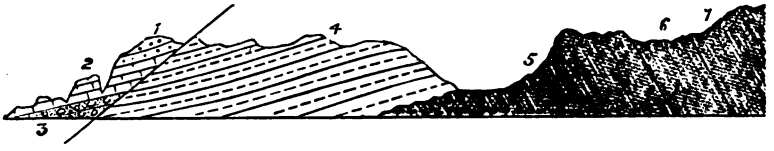
During the previous surveys of this district by Mr. Cox and myself the presence of loose trachy-dolerite boulders on the surface was always taken as evidence of an extension of

the Manukau breccias, but, as I have now shown, they are derived from the volcanic breccias interbedded with the Komiti beds. It is also probable that the solid volcanic bosses at Tokatoka, Maungarahu, Marahemo, and Coates's run, are of this age.

The sequence of the beds at Komiti, as now determined, is as follows :—

1. Orbitolite bed.
2. Yellowish tufas and breccias with lignite seams and silicified timber.
3. Coarse volcanic breccias.
4. Coarse sandstone with ironstone bands.
5. Sulphurous sandstones (with Crassatella beds).
6. Marly greensands with *Pecten zittelli*, &c.

Passing northward along the Arapaoa arm the following section is seen in a distance of 15 chains, clearly showing the relation of the Komiti Point beds to the older series :—



1–4. Komiti Point Tertiary beds. 5. Blue crumbling shaly clays, with irregular masses of indurated marlstone. 6. White or grey chalky clays. 7. Blue shaly clays, slightly sulphurous.

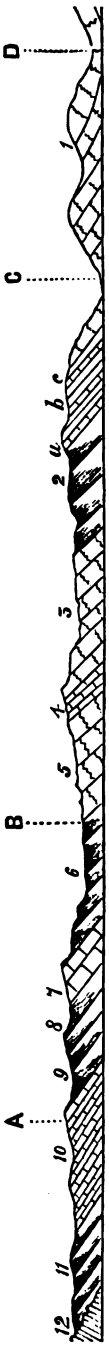
The younger beds strike E.–W.,* and dip S. at angles seldom exceeding 20°; and the older strike N.W.–S.E., with N.E. dip at an angle of 60°.

In the first bay past the Native settlement the shaly beds are overlain by fine-grained yellowish sandstones, in which I found a small Gryphæa. Their strike is N.–S., and dip W. at an angle of 45°. They are followed in turn by yellowish greensands, occurring in heavy beds, which are divided by blue-clay layers. For the next two or three miles the beach is bounded by low swampy mangrove-flats, beyond which the hydraulic limestone makes its appearance, and continues to Coates's farm, opposite Pahi, where it is underlain by marly greensands, which contain an abundance of marine shells.

McMurdo's House to Gibraltar Rocks. — The section from McMurdo's along the south side of the Pahi to Colbeck's boat-landing is perhaps the most important in the district, showing not only the relation of the Pahi greensands to the hydraulic limestones, but also the relation of the latter to the flaggy limestone at Skelton's Hill.

The hydraulic limestone continues half a mile past McMurdo's, to the north side of the Awakino, where it is underlain by blue clays and marly greensands, which are interbedded with three

* All the bearings are magnetic.



Section—McMurdo's to Colbeck's boat-landing. A. Colbeck's landing. B. Huritua. C. Awakino. D. McMurdo's. 1. Hydraulic limestone. 2. Blue clays and marly greensands with fossils, interbedded with three flaggy limestone bands (*a*, *b*, *c*). 3. Hydraulic limestone, 80ft. 4. Flaggy limestone, 20ft. 5. Hydraulic limestone, 60ft. 6. Marly greensands with flints. 7. White siliceous limestone. 8. Indurated calcareous greensands, forming reefs in river. 9. Marly greensands. 10. Hard flaggy limestone. 11. Marly greensands, with fossils. 12. Yellowish shaly clays.

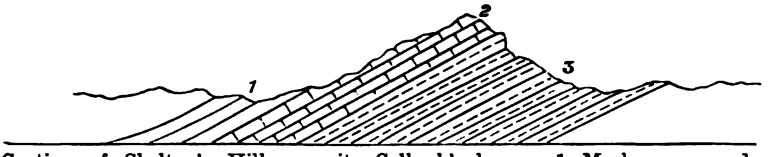
distinct bands of hard flaggy limestone near their junction with the hydraulic limestone. These bands are about 1ft. thick each, and consist principally of comminuted echinoderms and corals.

The marly greensands are next underlain by about 140ft. of hydraulic limestone, near the middle of which there is a bed of hard flaggy limestone about 20ft. thick, similar in character and composition to the thin bands just described. Then follow in descending order marly greensands with flints, white siliceous limestone, calcareous greensands, forming reefs across the river, marly greensands, hard flaggy limestone about 100ft. thick, marly greensands with fossils, and lastly yellowish shaly clays of probably Secondary age.

The only fossil found in the hydraulic limestone is a large radiating fan-shaped fucoid. Beds No. 2 are the Pahi greensands of former reports, and were largely collected from during my visit in 1885. The marly greensands (No. 6) contain large irregular masses of flint, which Mr. Cox wrongly credited to the chalk-marls during his survey of this district in 1880 (Geological Reports, 1879–80, p. 14). The hard flaggy limestone (No. 10), which is well exposed at Colbeck's boat-landing and at the Gibraltar Rocks, does not appear to exceed 100ft. in thickness. It is principally composed of broken echinoderm remains and corals.

The strike of the beds at Colbeck's is N.W.–S.E., and the dip S.W. at an angle of 55°. A small collection of fossils was made from the upper part of the marly greensands (No. 3), consisting principally of a small Turritella and Foraminifera.

The rocks (No. 12) on which the marly greensands rest unconformably, closely resemble in physical characters the shaly clays of the Inoceramus beds at Batley and Te Opu.



Section of Skelton's Hill, opposite Colbeck's house. 1. Marly greensands. 2. Hard flaggy limestone. 3. Marly greensands.

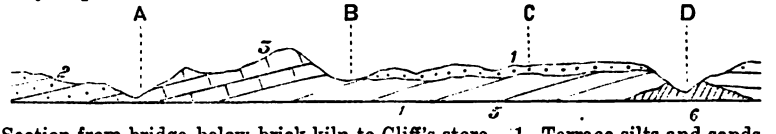
Gibson's, Te Opu.—The rocks at the point between Te Ope and Te Opu Creeks are sandstones interbedded with marly-greensand bands and blue shaly clays. The sandstones are brown and green in colour, and contain large concretionary boulders of indurated greensands, which frequently contain numerous broken plant-remains, and are often covered with a crust of cone-in-cone limestone. The boulders, where above the influence of the tide, decompose on the surface to a soft ferruginous sandstone. In one of these decomposed boulders I found fragments of a large Inoceramus, a cast of a small round echinoderm, with ambulacra in deep grooves, a Modiola, and casts of several other molluscs too indistinct for determination. Mr. McMurdo, of Pahi, who accompanied me to this place, informed me that on a previous occasion he observed in the centre of a large split boulder on the beach what he took for a "petrified tail." As the tide is continually shifting the stones on the beach, the boulder in question could not be found during my visit. The remains are probably those of a saurian. The beds here strike N.W.–S.E., and dip N.E. at an angle of 30°.

Pahi to Paparoa.—The section between these places is the same as that from Pahi to Colbeck's, being along an almost parallel line. The hard limestone is well seen on the road across Skelton's Hill. In places it is interbedded with green or brown sandstones, and in most places it weathers into flaky calcareous sandstones. It can be traced along the line of strike to within 20 chains of the Paparoa River, where it disappears in the low grounds, and is next seen on the banks both above and below the new bridge at the brick-kiln. At this place it presents an appearance more like a hard calcareous sandstone than a flaggy limestone. Proceeding up the river from the brick-kiln, it is underlain by marly clays, which in turn rest on fireclays, which are usually of a white, yellow, or blue colour. On the banks of the river, immediately opposite the cricket-ground, the fireclays are interbedded with a bed of carbonaceous shale, the actual thickness of which is not exposed, but must at least exceed 6ft. On analysis at the Colonial Laboratory (Laboratory No. 4565) it proved to be identical with the bituminous shales of Awanui and East Coast district of Auckland.

Carbonaceous matter	11·8
Water	16·2
Ash	72·0
	100·0

The beds dip S.W. at an angle of 5°. About 30 chains above this, behind Mr. Cliff's house, there is an outcrop of older rocks in the bed of the creek, consisting of yellowish slaty shales.

It is quite evident from this that the place to bore for coal is between the brick-kiln and Cliff's house. The cricket-ground is perhaps the best site that could be selected for this purpose. That there is an extension here of the coal-measures from Whangarei is clearly demonstrated by the section from Pahi to Colbeck's boat-landing, which is identical, almost bed for bed, with that at Kamo; but this does not guarantee the presence of coal, and, in the absence of surface indications, this can only be determined by boring. I do not consider the presence of carbonaceous shale an indication of coal; on the contrary, I think it may replace it.



Section from bridge below brick-kiln to Cliff's store. 1. Terrace-silts and sands. 2. Brown sandstones. 3. Calcareous greensands, with limestone bands. 4. Marly clays. 5. Fireclays with carbonaceous shale. 6. Yellowish shaly clays. A. New bridge. B. Lime-kiln. C. Cricket-ground. D. Cliff's store.

Paparoa to Bream Tail.—As already stated, the hard limestone, which is probably the horizontal equivalent of the Whangarei limestone, is well exposed on Skelton's Hill, beyond which the road trends on to the overlying marly greensands with flints, which continue to near Maungaturoto, where the overlying hydraulic limestones make their appearance. These continue some distance past Maungaturoto, and are then underlain unconformably by the old slaty shales and sandstones, on the east side of which the hydraulic limestone and marly greensands with flints again appear, and continue to the Hakaru, and thence eastward to Mangawai.

The Tara estate, situated at the sources of the Hakaru and Mangawai Rivers, is a large flat hill or spur composed of volcanic rocks, which decompose readily into a rich soil, which grows the most luxuriant vegetation, forming a striking contrast to the surrounding poor gum-lands. This peculiar rock weathers into rounded brown boulders, which might readily be mistaken for sandstone at first sight. The following is an analysis of a specimen of it by Mr. Skey in the Colonial Laboratory (Laboratory No. 4564) :—

Iron oxides, principally the protoxide	16·26
Alumina	7·64
Manganese	Traces
Lime	4·12
Magnesia	1·14
Water	8·12
Insoluble in acid used, principally silica	62·72
	100·00

REMARKS.—A greyish-coloured rock, slightly vesicular, and nearly homogeneous. It is easily affected by warm hydrochloric acid.

Greensands occur at many places on the banks of the Mangawai River which look like the coal greensands. They have been proved by boring to contain seams of coal, the thickest of which, however, was only 6in. through.

Light-coloured sandstones form the Mangawai North Heads, dipping N. at an angle of 55°. They are overlain by marly clays with flints. which continue to the entrance of the new gorge-road to Bream Tail.

The high range between Mangawai and the "Cove," which terminates abruptly on the coast at Bream Tail, is composed of slaty shales and sandstones that are well exposed in the heavy road-cuttings in the gorge. At the Cove the old rocks are overlain by a hard flaky limestone, with thin streaks of greensands dividing the flags. It fringes the coast to Waipu Bay, where the older rocks reach the beach.

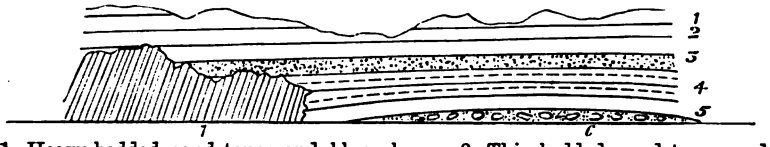
The older rocks at Bream Tail and Waipu are probably of Lower Secondary or Palæozoic age. They consist of argillaceous and siliceous slaty shales of a yellow or blue colour, and fine-grained indurated sandstones, generally green or dark-blue. The argillaceous rocks decompose to a great depth, and produce variegated clays that are difficult to distinguish from the highly-coloured clays at the base of the coal series. They sometimes contain hard siliceous or cherty bands, fragments of which are often seen scattered on the surface of these clays, thus giving the impression that the "chalk-marls with flints" are present, when such is really not the case.

The indurated greensands also decompose to a great depth, in favourable positions, into soft brown sandstones, which may be mistaken for younger rocks at first sight.

MOTUTAPU ISLAND.

The rocks forming this island are Tertiary sandstones and clays, lying on a highly-denuded surface of slates, sandstones, and breccias of probably Palæozoic age. The former occupy the whole of the western portion of the island, facing Rangitoto, and are lying comparatively undisturbed on the older rocks.

The sandstones and clays form a line of high cliffs rising to a height of 150ft. above the sea, which affords many opportunities of studying them to advantage. A fine section illustrating the whole sequence is seen at the north-west corner of the island, about a mile from the narrow channel which separates it from Rangitoto:—



1. Heavy-bedded sandstones and blue clays. 2. Thin-bedded sandstones and blue clays, 15ft. thick. 3. Gritty shell-bed, 3ft. 4. Blue sandy clays, 20ft. 5. Greensandstones, 6ft. 6. Coarse slate-breccia. 7. Old rocks.

The gritty shell-bed contains a large number of well-preserved fossils, of which an extensive collection was made, including the following forms: *Ostrea wullerstorfi*, Ostrea sp., *Pecten hochstetteri*, *Pecten burnetti*, *Pecten beethami*, *Rhynchonella nigricans*, *Terebratella dorsata*, *Crassatella ampla*, Leda sp., Perna sp., corals, sharks' teeth, echinoderm spines and plates, *Scalpellum aucklandicum* (n.s., Hector).

Most of these fossils are characteristic of the Cape Rodney and Kawau beds and the Papakura limestone. A new cirripede of gigantic size, which occurs plentifully in this bed, has been named *Scalpellum aucklandicum* by Sir James Hector, who has recently described it in a paper read before the Wellington Philosophical Society.

The coarse slate-breccia (Bed No. 6) contains *Ostrea wullerstorfi* and fragments of a large Pecten.

Cheltenham Beach.—From the volcanic breccia exposed in the seacliffs at the north end of this beach I collected the following fossils: *Pecten burnetti*, *P. polymorphoides*, *Terebratella dorsata*, and many fine corals, including *Fascicularia intermedia*, Tenison-Woods.

WADE DISTRICT.

Orewa to Okura.—From the bridge across the Orewa, on the main road from Auckland in the direction of the Wade, the beds are blue sandy clays, containing large concretions and septaria. They do not appear to contain fossils, the only signs of organic life being found in the septaria, which are crowded with broken plant-remains.

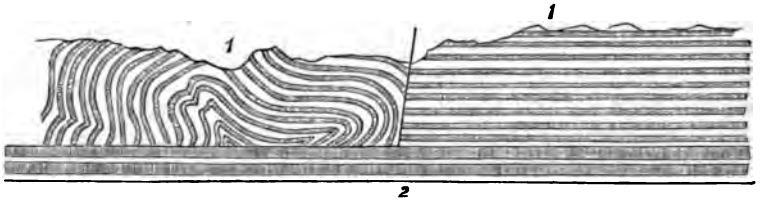
About 10 chains past the bridge, passing towards the Orewa South Heads, the rocks next seen are thin-bedded brown sandstones and blue clays, which a short distance beyond the Flagstaff Hill are underlain by heavy-bedded greensandstones with clay partings. These beds contain thin seams or layers of carbonised wood, and the peculiar radiating wormlike trail-markings which are so characteristic of the Pentacrinus beds on the coast north of Lake Takapuna.

The section from the Orewa Bridge to the South Head is as follows:—

1. Thin-bedded sandstones and clays. 2. Blue sandy clays with septaria.

Proceeding along the coast, from the South Head, in the direction of the Whangaparaoa Peninsula, the strata are found to be much disturbed in places, and at a point about half a mile past the Flagstaff Hill there is a very interesting and instructive example of how overlying strata may be folded and plicated with-

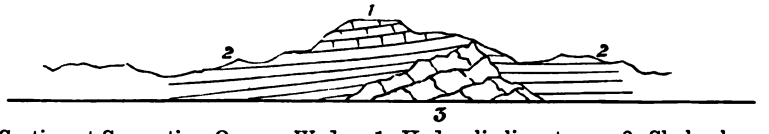
out disturbing underlying beds of a more rigid character, as shown below:—



Section half-mile south of Orewa South Head. 1. Thin-bedded sandstones and clays. 2. Heavy-bedded sandstones and clays.

Towards the peninsula the sandstones form broad, flat ledges, extending as shallow reefs far into the sea, and in many places they are jointed at right angles to the bedding and at right angles to each other. This cross-jointing often affects large surfaces, and, as the joints are filled with iron oxides, the ledges look like artificial pavements formed of large blocks set in red cement.

Serpentine at Wade.—On the east side of the main road there are two outcrops of serpentine between Wade and Okura, one of which—that nearest Okura—has been quarried for road-material. At the quarry the serpentine is of a dark-green or yellowish-green colour. It is rich in pyroxene, and contains titaniferous iron as disseminated grains. The rocks on the west side of this outcrop of serpentine are hydraulic limestones, and on the east side shaly clays with flinty concretions.



Section at Serpentine Quarry, Wade. 1. Hydraulic limestone. 2. Shaly clays, forming variegated clays. 3. Serpentine.

The outcrops of serpentine examined by me are quite isolated, and never more than a few chains in extent. Their exposure appears in all cases to be due to denudation, and, in consideration of the presence of the Palæozoic slates and sandstones near Bond's farm and at the adjacent islands, I am inclined to think they are the magnesian rocks which are invariably found associated with the Carboniferous or Devonian strata of New Zealand.

GENERAL REMARKS.

Before concluding this report it may be as well to briefly notice the correlation of the Komiti beds, and their relation to the hydraulic limestone, and the relation of the latter to the Inoceramus beds at Batley, Te Ope, &c.

The Komiti beds consist of a series of marine and estuarine beds, the deposition of which has been accompanied by contem-

poraneous volcanic outbursts of an extensive and wide-spread character. At Komiti Point they are interbedded with volcanic tufas and coarse breccias, which on the Wairoa side of the peninsula pass into solid lava-flows and massive dykes or bosses.

The marine beds contain a rich and varied fauna, to which the Mollusca supply the greatest number of species, the most characteristic in their upper division being *Crassatella attenuata, Ostrea wullerstorfi, Dosinia magna,* and *Pecten hochstetteri,* all of which are considered distinctive of the Awamoa series of Lower Miocene age. In their lower marly beds they contain, among other forms, *Pecten zittelli, P. fischeri,* and a number of corals, which indicate an extension downwards to the Grey-marls.

At Komiti Point the beds strike E.–W. (magnetic), and dip S. at an angle of 30°. At the point opposite Batley they lie on the upturned edges of the chalky clays belonging to the Inoceramus beds; and on the south side of the Otamatea, opposite Batley, they rest on the hydraulic limestone, but whether conformably or not I was unable to decide, as on account of the shattered and jointed condition of the limestone all trace of the original bedding is now obliterated. However, considering the very distinct mineral characters of the Komiti beds and this limestone, and the different conditions of their deposition, a certain degree of unconformity may be allowed at this point; but the lapse of time which this unconformity would represent must be very limited, judging from the very close affinities which exist between the fauna of the Komiti beds and that of the marly greensands conformably underlying the hydraulic limestone at Pahi.

Comparing the Komiti and Pahi beds with well-known horizons in the South Island, the following results are obtained:—

Upper Komiti beds.	Awamoa beds.
Lower Komiti beds.	Grey-marls.
	Ototara stone.
Hydraulic limestone.	Amuri limestone.
Pahi greensands.	Waihao greensands.
Fireclays, grits, and carbonaceous shale.	Fireclays, quartz-grits, and coal.

The absence of the Ototara stone in the North Auckland district has an important significance as indicating that during its deposition in the South Island a period of elevation existed in the north, thus permitting the hydraulic limestone to become denuded prior to the deposition of the Grey-marls. In 1885 I showed that an unconformity existed between the Waitemata beds and the hydraulic limestone, on account of which I considered the former to range from the Te Aute to the Awamoa series; but, in view of the facts just elicited, their higher division will probably be found to represent the Awamoa series, and their lower the Grey-marls.

The relation of the hydraulic limestone and underlying marly greensands to the Inoceramus beds is not so satisfactory as might be desired, but the evidence so far as obtainable strongly favours an unconformity between them. At Batley the hydraulic limestone is lying directly on the argillaceous and siliceous shales of the underlying series, but, as elsewhere in this district, it shows no distinct stratification. The shales strike N.W.–S.E., and at first dip S.W. at high angles, but between Batley and the Native settlement they are greatly disturbed, and, although they still maintain their general strike, they are now disposed in a number of shallow synclinal and anticlinal folds. Under these circumstances it is quite impossible to determine their relations to the limestone by the usual methods of stratigraphy; but a careful study of the geographical distribution of the latter tends to show that it is unconformable to the Inoceramus beds, as at different places it is found lying on the various members of this series. At the first creek on the Arapaoa arm, past Batley, it rests on the brown micaceous greensands, and at Batley passes over the outcrop of these on to the shaly clays, while at the pa it lies on the the lower shaly clays with septaria boulders containing Inoceramus. At Komiti Point, opposite Batley, the chalky clays and shales which are probably the lowest member of the Inoceramus beds exposed in the district also strike N.W.–S.E. at very high angles, which would carry them to Batley Heads, which are occupied by the hydraulic limestone. At Gibson's, near Te Ope Creek, where Inoceramus and other Secondary forms were obtained, the beds strike N.W.–S.E., and dip N.E. at an angle of 30°. The same strike was also observed at Te Opu and Whakapirau Creeks. The shaly clays were traced from the latter place to Marahemo, on the northern slopes of which they are in contact with the hydraulic limestone, which continues to the Pahi River, where it is underlain conformably by marly greensands, which are very distinctly bedded, and strike N.E.–S.W., or at right angles to the shaly clays. As at Batley, the hydraulic limestone is found lying on the different members of the Inoceramus beds. Between the Whakapirau and Pahi arms it rests on the shaly clays, while farther to the west it passes on to the lower micaceous sandstones. At Pahi Township the marly greensands, which conformably underlie the hydraulic limestone, rest on an outcrop of the brown micaceous sandstones which underlie the shaly clays with Inoceramus. The shaly clays on which the coal series rests at Paparoa closely resemble in mineral character the shaly clays of the Inoceramus beds, and, judging from the shingle in the bed of the Paparoa River, I think it is probable a development of Secondary rocks will be found in this direction.

Sir James Hector, who first discovered the Inoceramus beds in the Kaipara district, referred them to the Jurassic period, a determination which is fully sustained by the evidence since obtained.

ON THE GEOLOGY OF THE MALVERN HILLS, CANTERBURY.

NOTES BY ALEXANDER MCKAY.

NARRATIVE.

Wellington, 16th August, 1887.

FROM the 19th to the 23rd January, 1886, I was engaged in the Malvern Hills district of Canterbury, and was chiefly employed in making a collection of fossils from the Selwyn Rapids. On the completion of this work I went from Christchurch to Palmerston, Otago, on the 25th January.

REPORT.

The stratigraphical position of the fossiliferous beds exposed at the Selwyn Rapids has been correctly ascertained and fully described by Professor Von Haast, who also collected largely from the beds and their equivalents in other parts of the district—viz., Oyster Hill, Surveyors' Gully, Hart's Coal-mine, and other places mentioned in his report of 1871 on the Malvern Hills district. As in the Trelissick Basin, in the Middle and Upper Waipara, at the Weka Pass, and generally over the northern district of Canterbury, these fossiliferous beds lie between the greensand beds under the Amuri limestone and the coal-bearing beds at or near the base of the series of strata in the localities mentioned. The characteristic features of the beds and of those above and below them, and the unvarying sequence in the order of chalky limestones, greensands, concretionary saurian beds, and grey sands with coal-bearing strata, show conclusively that the Selwyn Rapids beds lie at the base of the saurian boulder-beds of the Waipara and Weka Pass sections, and also indicate that the Amuri group of the Amuri Bluff section is but an expansion of these marine beds, occurring there to the exclusion of the great bulk of the coal-bearing beds.

The collections from these beds in the Malvern Hills made by Professor Von Haast include, with one or two exceptions, only Tertiary genera, and have in most cases such close resemblances to specific forms found in the Tertiary strata of New Zealand, and such an absence of truly Secondary forms, that, admitting the equivalency of the beds as above indicated, it is remarkable that (except some rolled fragments of saurian remains and *Conchothyra parasitica*, and a species of oyster, which occur under the Waipara saurian beds and also at Amuri Bluff) the fossils should give so little evidence of their Secondary age.

Aware of these facts, it was in the hope of discovering such Secondary genera as are found in the same beds farther to the north-east that I made an almost exhaustive collection from the

beds at the Selwyn Rapids, and, failing the discovery of characteristic Secondary genera, to make such a collection that the species might be compared with those from the Waipara and Amuri Bluff beds on the one hand and with those of the coal-beds of South Canterbury and eastern Otago on the other, as for some years I have entertained the idea that in equivalent horizons the Secondary genera common in the north-east district of the South Island gradually disappear as the beds are followed through Canterbury into north-eastern Otago.

As bearing on this point, it may be worth while to quote a passage from Dr. Von Haast's report already mentioned: "The lowest fossiliferous bed assumes, according to the localities where it has been deposited, various distinctive features, so that, if two localities so close together as the Selwyn Rapids and the Oyster Hill, a mile south of them, are compared together, *we might almost believe that they belong to two different periods.** Thus the fossiliferous beds in the Oyster Hill consist of an agglomerated mass of large black oysters with scarcely any other shells between them, whilst the beds in the Selwyn contain a great quantity of conchifers, gasteropods, teeth and scales of fishes, without any oysters between them, showing that the conditions under which the oyster-beds were formed did not exist in that locality. Again, half a mile to the north-east of the Selwyn, that is to say, on the opposite side, the oyster-beds make their appearance once more, to the exclusion of all other shells. This occurrence might suggest to us that the conditions of the sea-bottom in the centre of the present valley and on both sides were quite different; for instance, that a river discharged itself into the sea a little higher up the valley, the sands and ooze here deposited preventing the formation of oyster-beds, which can only flourish in comparatively still water, whilst on both sides and a little more inshore these conditions existed. Many other molluscs which like a sandy or oozy bottom might, however, have selected the central locality as more congenial to their existence. . . . . My search for ammonites, belemnites, and other characteristic Cretaceous exuviæ was also in this district in vain, and I cannot conceive why the lower portion of the strata, resembling so closely those of the Amuri Bluff in sequence and lithological character, and having doubtless been deposited under similar conditions, should not, like these more northern beds, also contain belemnites, and some other characteristic fossils with Cretaceous facies, if they had existed in the sea at that period. Saurian remains exist amongst them, as in the Waipara beds, but they are neither numerous nor perfect, consisting mostly of rolled fragments."—(Report on the Geology of the Malvern Hills, Canterbury, 25th October, 1871, p. 24.)

* Not in italics in the original.

At page 68 of the same report Professor Von Haast describes the fossiliferous beds of the Selwyn Rapids, and gives a list of the species found in them as follows: "Comparing this [the] Oyster Gully section with that of the Selwyn [at the Selwyn Rapids], we find the sands overlying the brown-coal measures in the last-mentioned locality have dwindled to very small dimensions. They are succeeded by a bed of hard fossiliferous bluish limestone, with veins of calcareous spar. This rock has resisted the erosive action of the water to such an extent that portions of it stand as cliffs on both sides of the river, and in mid-channel 10ft. to 12ft. thick. It contains a considerable quantity of fossils, which however are often rolled and very fragmentary. I obtained from this bed, which dips E.S.E. 28°, a good many exuviæ, such as portions of the scapula of a saurian, teeth of Lamna and Hybodus, scales of the latter, Dentalium, Inoceramus, Cardita, Venus, Struthiolaria (?), *Conchothyra parasitica*, Natica, Dosinia, Lucina, Mesodesma, Pholadomya, &c. It is overlain by a hard bed of calcareous greensands full of fossils (Arca, Lucina, Tellina);" and from "overlying calcareous and micaceous sandstones of light colour" Professor Von Haast obtained "teeth and scales of fishes allied to Otodus and Hybodus, and casts of Turritella, Lucina, Panopæa, Dentalium, &c."

At the time of my visit the Selwyn River was extremely low, and the rocks in mid-channel at the Selwyn Rapids, described by Professor Von Haast, could be easily reached and collected from. The collection made under the circumstances, though large, can hardly be said to be exhaustive, since there are several genera mentioned by Professor Von Haast that do not occur in it, but on the other hand the total number of genera and species collected is considerably more than in the list given by Professor Von Haast, there being fully fifty species represented in the collection made. So far as worked out it contains neither saurian nor fish remains and no Inoceramus, Struthiolaria, Pholadomya, Arca, or Turritella, but supplements Professor Von Haast's list by the addition of the following genera: Aporrhais, Neritopsis, Scalaria (?), Ostrea, Pecten, Tapes, Pectunculus, Mytilus, and Modiola.

Specifically there is often a close resemblance to forms found in the Tertiary strata of these Islands; and on the abstraction of a few special forms, such as Conchothyra, Aporrhais, Trigonia, &c., the remainder of the collection might readily be mistaken on casual inspection as having come from Miocene strata. This is precisely the difficulty that was so perplexing to Professor Von Haast, and which this collection in itself has not made less, though, taken in conjunction with collections made later on in the season, it would appear that at last we shall have a key to the mystery, and an explanation of the highest practical importance.

These beds in the Selwyn River are seen also on the northern bank, and are there succeeded by sandy beds containing huge

septaria and concretions of a more arenaceous type. These often contain fossils, and some of them are crowded with *Conchothyra parasitica* occurring alone, while others contain a variety of shells. From these concretions I obtained vertebræ of a large fish (the same as found in the Grey-marls at Amuri Bluff), and amongst other shells two species of Trigonia.

ON THE GEOLOGY OF THE COAST-LINE, MOERAKI PENINSULA TO KAKANUI; AND FURTHER NOTES ON THE GEOLOGY OF NORTH-EAST OTAGO.

By Alexander McKay.

Wellington, 6th September, 1887.

The map accompanying my report on the young Secondary and Tertiary formations of Eastern Otago (p. 1, *ante*) was prepared to illustrate the geology of the district specially dealt with in that report, but it also shows the geology of the seaboard between Moeraki and the lower part of the Kakanui Valley. As the report above referred to only alluded to the Tertiary rocks on the coast-line between Shag Mouth and Waikouaiti, and scarcely made reference at all to the Palæozoic and Metamorphic rocks of the western part of the district mapped, it has been considered requisite that a description of the geology of the whole district should be given. The following notes supply what was wanting in this respect.

In the district the following formations and beds are represented:—

1. Recent.
2. Lower Miocene and Upper Eocene.
3. Calcareous sandstone = Ototara stone.
4. Marly clays (occupying position of Amuri limestone).
5. Waireka tufas.
6. Onekakara sands, &c.
6A. Moeraki boulder-beds.
7. Greensands.
8. Katiki Beach beds.
9. Limonitic sandstone.
10. Coal-beds and Horse Range conglomerates.
11. Breccias, sandstones, and blue slates.
12. Blue Mountain limestone.
13. Schists in the area west of Shag Valley.
14. Miocene volcanic rocks.
15. Cretaceo-tertiary volcanic rocks.
16. Felsite dykes, &c.

1. *Recent Deposits.*

Recent deposits, as river alluviums, form the flat lands of the Lower Kakanui valley, the materials of which consist of sandstone gravels overlain by a loamy deposit. The gravels of this deposit are for the most part derived from the sandstones forming the

great bulk of the Kakanui Range; but, besides these, basic volcanic rocks of Cretaceo-tertiary date show frequently in the shingle of the river-bed.

South of Kakanui mouth loess or sandy loam caps the Lower Miocene strata, showing in the cliffs along the shore of Allday Bay, and extends inland towards Maheno and Herbert (Otepopo) to a greater extent than shown on the map, the Beds No. 5 of the map being unquestionably continuous between the Waianakarua (Otepopo) River and the Kakanui at Maheno. A small area of recent deposits has been shown north of the mouth of the Waianakarua River, and the same beds extend for an equal distance along the south bank of the river, though not shown on the map, the reason for this being that I have shown the underlying rocks at all places where their character and age could be determined with certainty.

Over the larger area of the Moeraki Plain, between the northern end of Onekakara Beach and the forks of the Otepopo–Waianakarua River, the recent deposits at the surface have been mapped: first, because there may be some doubt as to the boundaries of Beds Nos. 5, 6, and 6A, obscured by such gravels; and, secondly, the gravels themselves cover an area so extensive that their not being represented on the map would convey a wholly wrong idea of what may be seen at the surface over a considerable tract of country. As a matter of fact these gravels extend farther in the direction of Hampden than shown; but in this part the underlying rocks are clearly seen in all the creeks and along the coast-line, and it is requisite to bear in mind that the limits and disposition of the various divisions of the Cretaceo-tertiary series, and not the correct delineation of the Pleistocene geology of the district, were the object of investigation.

It has been casually mentioned that the recent deposits of the Moeraki Plain and of the downs south of this to near Hampden are formed mainly of gravels. These are partly littoral, but mainly are deposits by the Waianakarua at a time when it discharged into North Moeraki Bay, between Hampden and Lookout Bluff.

Next to the south there is an area of recent deposits at the mouth of Trotter's Creek, and higher up the course of the stream there are alluvial flats (not shown on the map) as far as the eastern boundary of the limonitic sandstone (Beds No. 9), and the next considerable area farther to the south forms the banks of and low grounds along the Shag River for seven or eight miles of its course. South of Shag Mouth high-level gravels cap the cliffs on the coast, or lie a little inland of the sea-face at heights of more than 100ft. above the sea. These are composed, at places, of rather coarse material, but yet may be the remnants of an old beach formed at a time when the land stood at a lower level: more probably they are river-deposits formed at a time when the land

extended much farther to the eastward, and before the Shag River had cut down to its present level or the sea had encroached to form the high cliffs that stretch south along the coast-line. Between the mouth of Stony Creek and Goodwood's Lagoon is a sandspit or raised beach of small extent, and the next considerable area of alluvium lies within the valley of Pleasant River approximately within the limits shown on the map; and, finally, there is at Waikouaiti an extent of turbary, alluvial, and æolian deposits.

2. Lower Miocene and Upper Eocene.

With the exception of a short distance north and south of Bobby's Head, the higher of these rocks are continuous on the coast-line from Shag Mouth to Cornish Head. They dip at moderately low angles to the eastward, and consists of grey sands and sandy clays, with hard calcareous bands at places. Fossils in the higher beds are not plentiful at most places accessible on the coast-line. South of Shag Mouth the following forms were collected: Natica, Turritella, Solenella, Nucula, a crustacean, some echinoderms, and Foraminifera. The number of species is too small to decide from them alone the age of the beds, but neither the age nor the position of the beds is doubtful.

On Bushy Park Estate, at the boundary of this formation, opposite Puketapu, and resting on calcareous sandstones belonging to the Cretaceo-tertiary series, the lowest bed of No. 2 consists of a ferruginous concretionary band, in which shells as casts are abundant. Among these are *Voluta pacifica, Turritella gigantea, Trochita neozelanica,* Cytherea, *Dosinia magna,* Cucullæa sp., and a number of badly-preserved shells. And forming the northern end of an isolated hill on the left bank of the upper part of Stony Creek is a rusty-coloured calcareous sandstone largely composed of broken shells of Balanus. In this I found *Waldheimia lenticularis* (?) and *Pecten hochstetteri.*

Following the coast to the north, beds of this age are not met with till reaching Allday Bay, where the Miocene beds show in the sea-cliffs, and at the north end of the bay are seen to rest on, or rather gradually pass into, the Upper Eocene or Hutchinson's Quarry beds that there rest on a slightly uneven surface of Ototara stone.

In the higher beds of this section fossils are comparatively rare. The lower beds (Hutchinson's Quarry beds) have a thickness of not more than 30ft., and are here a dirty greensand evidently largely composed of volcanic material that closely resembles the beds following the Ototara stone where the latter crosses Oamaru Creek at the Devil's Bridge opposite Teaneraki. Following Oamaru Creek down, the Hutchinson's Quarry beds are on its left bank overlain by Awamoa beds full of fossil shells. The same relation of the Awamoa beds to the Hutchinson's Quarry beds is seen at the end of the Awamoa Beach, on the south-west side of

the Cape Hills, Oamaru; and it is thus evident that in this district at least there is an apparent, if not a real, conformity.

As respects the section at the northern end of Allday Bay, there can be no doubt of the conformity of the two, but, as has been hinted, the beds there yielding the fossils of the collection made, and apparently those mentioned by Professor Hutton (Trans. N.Z. Inst., 1886, Vol. XIX., p. 423), belong to the Hutchinson's Quarry beds, and yield forms not found in, and others that are rare in, the Awamoa beds.

Among the fossils from the first 20ft. of strata overlying the Ototara stone are *Voluta pacifica, Scalaria lyrata, Struthiolaria senex, Pleurotomaria tertiara,* Cardita (the same as from the Kekenodon beds in the Waitaki valley), *Gryphæa tarda* (?), *Ostrea wullerstorfi, Lima multiradiata, Lima lævigata* (?), *Pecten polymorphoides, Pecten hutchinsoni,* Terebratula, *Waldheimia sinuata, Cellepora nummularia, Flabellum radians, Balanophyllia alta,* and Isis, in even far greater abundance than the same species at Hutchinson's Quarry. Altogether some forty species of shells and a large collection of corals were obtained, the general character of which is not such as might be expected from the higher beds. From the higher beds but a few fossils—Solenella, Turritella, and Nucula—were obtained, and their difference in character warrants the same distinction between the lower and the higher Tertiary beds of this section as has been made in the case of the Awamoa Beach section.

With respect to the relation of these beds to the Ototara limestone in the section at Allday Bay, unconformity is not so pronounced as to place this beyond all dispute. There is certainly no abutting of strata in a highly unconformable manner, but the surface of the Ototara stone appears to have worked into it "pot-holes" that have been filled by the calcareous greensand of the next succeeding beds, which, in character, is quite distinct from the Ototara stone; but it must also be said that there appear to be enclosures of this calcareous greensand in the Ototara stone, which it is impossible to judge of as other than a contemporaneous rock. The more calcareous and harder part of the Hutchinson's Quarry beds is, on the average, little more than 1ft. thick, and this is suddenly succeeded by loose friable greensands of the character already described, and which contain the same fossils as the lower harder portion of the Upper Eocene beds.

3. *Calcareous Sandstone=Ototara Stone.*

With the exception of a small area immediately south of Kakanui Mouth these rocks are confined to the coastward part of the district from Shag Valley south.

Everywhere south of Shag Mouth these beds are formed of yellowish calcareous sandstones, and at most places this is underlain by a bed of greensand of variable thickness. Fossils are not

abundant, such as have been collected belonging to the genera Fusus, Voluta, Natica, Pleurotomaria, Pecten, Waldheimia, Flabellum, &c. The beds extend along the coast-line some considerable distance south of Waikouaiti and in this direction continue to be underlain by greensands.

4. *Marly Clays.*

These beds appear farthest to the north in Look-out Bluff, and are there seen to underlie the volcanic rocks forming the higher part of the hill, and they overlie the Waireka tufas (Beds No. 5), both having a S.E. dip. Dipping to N.E., darker-coloured beds appear on the south side of the Bluff; but here the beds strike out to sea. They are next seen in the outer part of Moeraki Peninsula, crossing this in a nearly southerly direction, and are not again met with before reaching the south-west slopes of the Horse Range and Shag Valley. In Shag Valley they surround Janet's Peak, and strike along the western middle slopes of Puketapu and Mount Royal; and, outcropping from below the calcareous sandstones (Beds No. 3), they again appear between Pleasant River and Waikouaiti. Comparatively few fossils have been found in these beds within the area shown on the map accompanying the report on the north-east district of Otago; but on the north bank of the Kakanui, opposite Maheno, the same beds abound in Foraminifera and small shells. A few Foraminifera were obtained from the beds in Look-out Bluff; and in the gullies south-east of Janet's Peak *Pecten zittelli*, Leda, and Foraminifera are not rare in particular situations; and on the west slope of Puketapu and of the saddle between Puketapu and Mount Royal the same fossils are found.

These beds, as they underlie the calcareous sandstones already described, are supposed to form part of the sequence affected by the fault along Woolshed Creek and the south-west slopes of the Horse Range; and, although neither they nor the Onekakara sands are clearly seen, this is due only to the presence of Pleistocene deposits obscuring the strata under the calcareous beds till reaching the Moeraki boulder-beds.

5. *Waireka Tufas.*

These are not seen in the southern part of the district, and I could not be certain of their identity in Moeraki Peninsula. From Look-out Bluff they are continuous to the Waianakarua River, and thence form cliffs on the coast-line to Aorere Point, the south headland of Allday Bay. Inland they reach to Mount Charles and the Township of Herbert, and north to Maheno, opposite which place they are seen to pass under Beds Nos. 3 and 4. From Look-out Bluff these beds can be traced north to the south bank of the Waianakarua River, and from the opposite bank to Mount Charles, Maheno, or the south head of Allday Bay respectively; and there can be no doubt of three things: (1) That they overlie

the Onekakara sands (Beds No. 6, next to be described); (2) that they underlie the Hutchinson's Quarry and Awamoa beds of Allday Bay; (3) that they pass under the Ototara limestone, and are identical with the tufaceous beds (volcanic sandstone of Hutton) forming the floor of the Waireka Valley.

6. *Onekakara Sands.*

These beds are greenish or dark-grey sands, sometimes argillaceous to a considerable degree. To the north they begin to be seen on the banks of the Waianakarua, and the section from the railway-crossing along the river-banks shows these beds resting on the Moeraki boulder-beds, and passing under Beds No. 5, already described. The same beds begin on the Onekakara Beach, three-quarters of a mile south of Look-out Bluff; and, but for the northern part of the beach having Pleiostocene gravel-cliffs reaching to sea-level over a distance of half a mile, the beds here would have been seen passing under the Waireka tufas as clearly as on the banks of the Waianakarua. Along the beach on the north side of Moeraki Peninsula these beds are present, and form low flat reefs on the shore within the tideway; they also show in the seacliff and road-cuttings, but are here disturbed by slips and obscured by volcanic rocks. They are developed along the north-east side of Shag Valley between Janet's Peak and Kitchener's, above Dunback, and here the Moeraki boulder-beds cannot be distinguished, so that both have been mapped together. This is also the case with respect to these beds south of Shag Valley.

Fossil collections were made from these beds on the banks of the Waianakarua at Onekakara, Moeraki Peninsula, and in Shag Valley. No complete list of the species collected can be given, the collections probably including many species that require description; but the following genera and species serve to indicate that here, as at the Waihoa, in South Canterbury, a mere consideration of the fossils might lead to the belief that the beds belong to a horizon higher in the sequence than they actually occupy—a subject which I have treated fully in a preceding report. The following genera and species, or representative species, occur: *Aturia ziczac, Dentalium mantelli,* Fusus sp., *Siphonalia nodosa,* Fasciolaria sp., *Triton minimus, Pleurotoma fusiformis* and three new species of Pleurotoma not before collected, Murex sp., Oliva, *Natica neozelanica* (?), *N. suturalis, Turritella ornata, T. ambulacrum, T. rosea,* Trigonia, Cucullæa, Limopsis, Nucula, Leda, *Pecten hochstetteri,* Pecten sp., and numerous corals and Foraminifera.

6A. *Moeraki Boulder-beds.*

These underlie the Onekakara sands, and their relation both to these and to the underlying greensands is clearly seen in the various small rivers and creeks between Moeraki Plain and the lower part of Trotter's Creek. I could find no fossils in these

beds, but the boulders are often covered with a layer of cone-in-cone limestone, and particular boulders show the structure of this peculiar rock so perfectly that from one of these a large collection of samples was taken. The Moeraki boulder-beds are present along the fault-line between Woolshed Creek and the south-west slopes of the Horse Range; more to the south, as already stated, they are not clearly distinguishable from Beds No. 6.

7. *Greensand.*

These next underlie, and are easily traceable from Otepopo Tunnel to Katiki Beach, and the same beds underlie the Moeraki Boulder-beds in Woolshed Creek, and from Palmerston extend continuously to Waikouaiti.

8. *Katiki (Kartiki) Beach Beds.*
9. *Limonitic Sandstone.*
10. *Coal-beds and Horse Range Conglomerates.*

These between North Peak and the Waianakarua extend along the eastern lower slopes of the Kakanui Mountains. The Katiki Beach beds scarcely more than reach the first hill-slopes west of the railway. Most of the small rivers have cut through the limonitic sandstone and coal-grits, while the latter are yet preserved on the tops of the spurs, making the western boundary-line of the coal formation extremely sinuous, which line is but approximately indicated on the map. South-west of Hampden these rocks have been fully described in the report on the north-east district of Otago.

11. *Breccias, Sandstones, and Blue Slates.*
11A. *Blue Mountain Limestone.*
12. *Argillaceous Beds, semi-metamorphic.*

These constitute the rocks of the Kakanui Mountains, and were not examined except along the boundaries of the younger series of beds. They have been described in former reports by Mr. Cox and myself.

13. *Schists.*

West and south of Shag Valley these form the basement on which rests the coal-bearing series, and are exposed in all the deeper gullies over the area covered by the quartzose grits at the base of the younger series.

Volcanic.

14. *Miocene Volcanic Rocks.*

Some of the volcanic rocks of Moeraki Peninsula may be of this age, but of this there is no distinct proof, as the sedimentary beds on which they rest are not younger than the Ototara limestone. The basic rocks forming the higher part of North Peak

rest on quartz-grits, &c., that belong either to Beds No. 9 or No. 10, but whether these are of the same character and of the same age as the youngest lava-streams in Moeraki Peninsula has yet to be determined. It is probable that this is the case, and that such rocks are of the age of the volcanic rocks capping Puketapu, Mount Royal, and a number of conical peaks south of the lower part of Shag Valley.

In this part of the district the volcanic rocks, which are old lava-flows, lie on all the different members of the Cretaceo-tertiary series, and at Bobby's Head are seen to have broken through and disturbed the youngest of the Miocene rocks of the district, so that there can be no doubt that they belong to the Upper Miocene or to the Pliocene period.

15. *Cretaceo-tertiary Volcanic Rocks.*

To these belong the lower volcanic rocks in Moeraki Peninsula, where the rocks are the same as the grey dolerites of Mount Charles, Otepopo, and here occupy the same or nearly the same horizon in the sequence of the sedimentary beds.

16. *Felsite Dykes.*

Under this head has to be noted a massive dyke of grey felsite rock running parallel to or occupying the line of fault commencing near the Main North Road over the Horse Range, and traceable north-west along the line of fault to nearly opposite Hutchinson's lime-kiln, north of Janet's Peak. This rock is of a light-grey colour, and contains minute specks of what appears to be augite, and microscopic grains of a clear transparent quartz-like mineral.

ON THE RECENT VOLCANIC ERUPTIONS AT TARAWERA.

PRELIMINARY REPORT BY DR. HECTOR.

[Reprinted from App. Jour. House of Representatives, H.-25, 1886.]

To the Hon. the MINISTER of MINES.

SIR,— Wellington, 23rd June, 1886.

I have the honour to report that, according to instructions from Government, I proceeded to Tauranga on the evening of Thursday, the 10th instant, in the "Hinemoa," and arrived there on Saturday afternoon.

At Tauranga I engaged the services of Mr. Spencer, a skilful landscape photographer; and on Sunday our party, seven in number, drove to Rotorua by the Oripi Road, the ordinary route by Te Puke being blocked.

On Monday I proceeded to Wairoa with Captain Mair, who joined the boat expedition which had been organized to search the Native settlements on Tarawera Lake. On the same day I sent my assistant, Mr. Park, to the south of the disturbed area by way of Kaiteriria; and on Tuesday, following the same route, I examined the vicinity of Rotomahana. Mr. Spencer, with his camera, accompanied me everywhere, so that a series of well-selected views of the eruption and its effects was obtained.

On Wednesday we started for Taupo, feeling anxious to complete the general view of the whole line of volcanic activity from Ruapehu to White Island, as alarming rumours were in circulation as to the extent of country that had been affected. By this route we also obtained a distant but interesting view of the newly-raised cones of Tarawera from the eastward.

The incidents of the eruption have been so fully described by the Press that it is unnecessary for me to refer to them in this preliminary report, the chief object of my rapid inspection having been to ascertain the exact locality, nature, and extent of the outbreak, and its probable consequences to the district. A complete geological examination of the district has therefore been deferred until a more favourable season for field-work, and until the volcanic activity has sufficiently subsided to admit of accurate observation.

The focus of the disturbance was ascertained to be in a line extending from seven to ten miles in a north-east to south-west direction from the north end of the Tarawera Range to Okaro Lake, in position A B on the accompanying diagrammatic plan (Plan II.). The northern part of this line is occupied by the Tarawera Range. This range has three summits, the northernmost being Wahanga; the central, Ruawahia, 3,606ft. alt.; and the southernmost Tarawera mountain proper.

The southern part of the line previous to the outburst was a depression occupied by Rotomahana Lake, surrounded by low undulating country composed of pumice-sands and overspreading deposits of siliceous sinter, most of which were connected with active geysers, amongst which the most famous were those at the Pink and White Terraces.

From the most reliable evidence it appears that the outbreak commenced at ten minutes past two on the morning of the 10th, by an eruption from the top of Wahanga, attended by a loud roaring noise, and slight earth-shocks. In a few minutes this was followed by a similar but more violent outburst from the top of Ruawahia, the middle peak of the range, and after a short interval this phase of the eruption culminated in a terrific explosion from the south end of Tarawera Range, north-east of Lake Rotomahana. For nearly two hours this was the only phase of the eruption, and was accompanied by the ejection of vast quantities of steam, pumice-dust, and hot stones, forming huge towering clouds, illuminated by lightning flashes.

It was at this time also that a great crack or fissure (A C on Plan II.) was formed along the east face of the Tarawera Range. I only had a distant view of this fissure from the eastward, but Mr. Percy Smith, the Assistant Surveyor-General, who had a near view from the south side, reports that the whole east end of the mountain has been blown away, and that the *débris* covers the country to a distance of many miles. The white terrace of pumice-sand that I saw was singularly flat-topped, and seemed to slope abruptly from the mountain like a huge embankment 500ft. high. Besides these heavy sands that lodged close to the fissure in the mountain-side, the lighter dust was spread out in the form of stratified clouds, which were distinctly seen, at this period of the eruption, from Rotorua, Tauranga, and Taupo.

The cloud thus formed discharged its contents for the greater part in a direction to the eastward of the mountain, reaching as far as Te Teko and Fort Galatea, and to the westward as far as Wairoa. The earth-shocks, however, during this period of the eruption do not appear to have been of extreme violence, or to have created much alarm beyond that part of the district lying in the immediate vicinity of the volcanic eruption; but shortly before four a.m. a violent outbust of a totally different nature was experienced, accompanied with loud reports that reverberated through the atmosphere to enormous distances. The first notice of this outbreak was an earth-shock that appears to have been much more widely felt than those previous, and chiefly in areas where hot-springs occur. This development was attendant on the outburst of an immense volume of steam—carrying pumice-dust and fragments of rocks to an enormous altitude—which proceeded from the site of Rotomahana Lake, causing the formation of a dense cloud in the higher atmosphere, that spread in definite directions, its advancing edge being marked by electrical discharges of the most awe-striking character.

At first the wind was from the south-east, and the inhabitants of Rotorua appear to have been terrified by the approach of this hideous cloud, when suddenly the wind sprang up from the south-west and arrested its progress in that direction, turning it off towards the north-east, at the same time condensing the vapour of the cloud to such an extent that the suspended solid matter dropped on the surface of the earth in the form of mud, smothering the country, and leading to the disastrous results experienced at Wairoa.

By six a.m. the period of active eruption appears to have closed, and since then the display of energy in a modified form has also rapidly declined.

The following are the chief points which require notice in this report:—

I. FOCUS.

Tarawera Range, about 3,600ft. above sea-level, is an isolated and very conspicuous object in the scenery of the Lake District. It slopes from Tarawera Lake—the level of which is about 1,000ft. above the sea—and previous to the eruption rose very abruptly, with mural precipices and columnar rocks, especially on its western and southern escarpments. It was, no doubt, judging from this feature that Dr. Von Hochstetter was led to class Tarawera Mountain with the Horohoro Range, as being part of his older or submarine-formed volcanic series, and a remnant of the great plateau,* the surface of which denotes the original level of the country prior to the production of its present broken surface by the excavation of valleys, by the upbursting of volcanic mountains, and the consequent subsidence or breaking-in of large cavities that are now occupied by lakes. He nevertheless maps Mount Tarawera as belonging to his recent volcanic series, and also alludes to it in other parts of his work as being composed of obsidian.

I have never ascended the Tarawera Range, but have examined its slopes and found them to be composed of lavas of a highly acidic or rhyolite type, in the form of flows intersected by dykes, and containing, amongst other rocks, large quantities of compact and vesicular obsidian. From this I conclude that the mountain really is one of recent volcanic origin, belonging to Von Hochstetter's new volcanic series, and that its abrupt outlines have resulted from fractures and subsidences of its flanks. According to this view it is natural to assume that the still-imperfectly-cooled mass of lava in the heart of this volcanic mountain has given rise to the long-continued (historically speaking) solfatara action at high temperatures that created the attractive wonders of the Rotomahana. It has been stated that no Native tradition exists of Tarawera having been the site of previous activity; but the range culminates in three distinct peaks, the meaning of the Maori names of which—according to Mr. Locke, M.H.R., and other authorities—clearly contradicts this assumption. This consideration has interest, as a sudden development of volcanic activity in a new locality, or in an ancient and greatly-denuded formation like the trachyte breccia that forms the Horohoro, would have been more serious and significant than the mere temporary revival of the expiring energies of a recent focus of volcanic force.

II. THE VENTS.

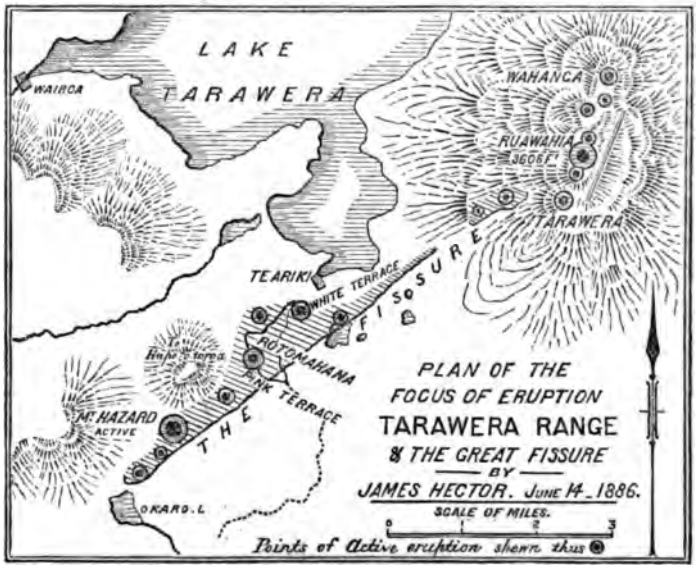
As viewed across Rotorua Lake, on the 13th, from the point where the Tauranga Road emerges from the bush, Tarawera Range appeared to have quite lost its former characteristic outline. The deep gap dividing the Wahanga, the northern peak, from Ruawahia, the central one, was almost obliterated, and the abrupt, pre-

* *Vide* Hochstetter: "Reise der 'Novara,'" Vol. I., p. 106.

cipitous sides of the mountain were everywhere softened by great slope-deposits of material ejected from the volcanic vents, consisting of stones and dust of a grey colour.

Along the edge of the range seven distinct points were seen to give off steam from flattened conical heaps of dark-coloured *débris*, and at intervals these vents threw off large volumes of steam and vapour, darkened to a reddish hue by solid matters, which were discharged to a height estimated at from 200ft. to 500ft. Four days later, when viewed from the eastward, the same range showed a similar appearance, allowing for the change in direction; but the cone on the summit of Ruawahia had evidently accumulated with greater rapidity than the others, and had acquired lateral cones, giving its outline a similar appearance to that of Rangitoto, near Auckland.

During two clear nights I watched the eruption from these vents, and could distinguish them against the sky with a powerful binocular telescope; but I never observed any illumination of the ascending steam-clouds, as if from the surface of an incandescent mass within the vent, nor was there any sign of any outpouring of lava, either from these vents or from cracks or fissures in the sides of the mountain, during the time of my visit. In addition to the above-mentioned conical vents on the summit of the range, along its eastern side the line of fissure already alluded to was distinctly visible, emitting wreaths of steam. This line of fissure lay in an oblique direction, so that it appeared to gain in elevation along the sides of the mountain from north towards south, but not sufficiently so to indicate for it a direction that would make it continuous with the great fissure south of Tarawera, but rather in the direction of the short double line shown on the plan below :—



It is below this fissure-line on the eastern flank of the range that bulky terrace-like accumulations of pumice-sand have been formed; and if this eruption should ever reach the stage of producing lava, which from other circumstances I think hardly likely, it is from this fissure that I should expect the lava to exude.

III. THE GREAT FISSURE.

This is the most remarkable and characteristic feature of the late eruption, and the chief origin of the disastrous results which attended it. A good view, but much obscured by steam, was obtained from the hill called Te Hape-o-toroa—alt., 2,300ft.—by Mr. Park on the 14th, and by myself on the following day. This fissure seems to commence as a narrow rift at the northern end from the great rent which has been formed in the south end of Tarawera Mountain. This rent is a most wonderful feature. It is not a slip from the mountain-side, but appears as if a portion of the mountain, measuring 2,000ft. by 500ft., and 300ft. deep, had been blown out, leaving a ragged, rocky chasm, from which steam was being discharged in rapidly-succeeding puffs. The eastern side of this chasm was brightly tinted, as if by the efflorescent deposit of a mineral substance, probably ferrochlorides.

Sulphur has been mentioned as a deposit from this recent outburst from some who have witnessed it; but this is hardly a possible result of such rapid volcanic developments.

The view I obtained of the extent of this chasm south was much obscured by numerous volumes of steam blowing off from the newly-formed fumaroles that occupied the site of Rotomahana. From the eastern slope of Te Hape-o-toroa we looked right into the fissure, and, as far as I could see, it appeared to have a nearly straight boundary of undisturbed ground on its eastern side, extending from the Tarawera chasm to within a few chains of Lake Okaro, thus intersecting the Rotomakariri or the Cold Lake, the Rotomahana Lake, and the valley extending from thence southward. The west side of the fissure, on the other hand, is very irregular in outline, and is continually being altered by the falling-in of its precipitous walls, as the hills are undermined by the action of powerful geysers, seven in number, which at irregular intervals throw up great volumes of boiling water, with stones and mud, to a height of 600ft. to 800ft. from the bottom.

It is only by occasional glimpses during the breaks of the steam that any idea can be formed of the nature of the bottom of this huge fissure; but it seemed as if it was entirely occupied by large circular areas of mud, seething and boiling in such a fashion as to convey the impression of its being in a very liquid state. These mud-pools are separated from one another by comparatively solid ground, and in some cases, especially towards the eastern side of the fissure, what appear to be small pools of water with sedgy margins could even be distinguished; but the difficulty of esti-

mating distances and depths through the steam-clouds rendered the observations made very uncertain.

The largest of these mud-geysers appeared to be that rising from the position formerly occupied by the Pink Terrace, but the most interesting is one a mile farther south, which, unlike the others, does not spring from the bottom, but from the comparatively high ground on the west side of the fissure, and, owing to the obliquity with which the fragments are thrown out, is gradually building up a conical mound, which already has attained an altitude of several hundred feet (Mount Haszard on plan). At the southern extremity the fissure is bounded by a bold semicircular extremity, from the base of which powerful steam-jets are escaping; but there was no evidence that it was prolonged by a crack or fissure, or fault, or other displacement of ground, nor was there any evidence that the fissure had been produced by any inequality of the movement of the ground bounding it, but rather that it was caused simply by the removal of material which formerly occupied its space. Its direction, as far as could be ascertained, is N. 50° E., which is the general line of direction that would connect all the more active geysers between Tongariro and White Island.

IV. MATTER EJECTED DURING THE ERUPTION.

The quantity of matter which was ejected during the different phases of the eruption was very large. In the first place, stone fragments were scattered from the earlier eruptions of Tarawera over an area of country extending to the eastward as far as Te Teko, and even, some say, to Fort Galatea; while in the opposite direction they are not reported to have fallen at any place farther west than Wairoa, a distance of six miles. None of the fragments which I collected are other than portions of rocks of the district, nor do they present in the slightest degree the character of volcanic bombs or lapilli formed from lava or rock-material in a state of fusion. Yet there can be no doubt, if we can accept the evidence of the eye-witnesses, that these rock-fragments must have, in some cases, reached the ground in a partially incandescent state. Next followed the great ejection of pumice-sand, which forms enormous deposits in two localities: the one is on the eastern slope of Tarawera Mountain, already described, the nature and origin of which I had no opportunity of ascertaining. The other deposit of this nature is chiefly on the western side of Rotomahana fissure, and was no doubt ejected at the commencement of the second phase of the eruption. Over a district of twenty-four square miles south of Tarawera Lake, and on an almost equal area to the north and east of the lake, the whole surface of the country has been covered with this pumice-sand so thickly as to obliterate in a great measure the natural features, partly filling the gullies, and enveloping all the hills as if with a deep mantle of snow, so that not a

trace of vegetation can be seen, from the highest peaks, such as Te Hape-o-toroa, which is 2,300ft. above the sea, down to the level of the lake. The thickness of this deposit could not be ascertained at the time of my visit, as no slips had occurred in it and no sections were to be seen. It consisted of fine-grained and gritty pumice-sand, slightly crusted on the surface by the action of the rain, which also caused it to assume a slightly greyish tinge; but underneath it was a pure white, and at a depth of 12in. to 18in. from the surface had still a high temperature on the sixth day after the eruption.

Lying on the surface of this deposit, especially on the slopes directed towards the fissure, fragments of considerable size of various kinds of rocks were scattered about, and among these were masses evidently derived from the sinter of the terraces, and, from the manner in which these fragments appeared to occur in quantities where the finer dust had been blown from the surface, it is probable that the lower layer of the deposit will prove to be composed of coarser material than the upper. The boundary-line of this dazzling white deposit is very distinctly marked. It can be well seen where it passes over Kakaramea Mountain, dividing it, as it were, into two portions, one white and the other green. While traversing it we experienced a great downpour of rain, which formed the powdery material of the surface into little pellets; but it did not appear to be very absorbent, or to show any tendency to work up into an adhesive material. This is very different from what may be termed "the grey deposit" which is next to be mentioned, and which covers the country, from about two miles south of Wairoa, in a northerly direction towards the Bay of Plenty, as far as the Te Puke settlement. This is the mud-forming deposit, and wherever it appears to have descended in a thoroughly pasty condition it coated the vegetation so heavily as to break limbs off lofty trees and to crush the smaller scrub flat simply by its weight. The sand, as already stated, appears to have fallen hot, so hot, indeed, as to set fire to the trees, the stumps of which were seen burning in many places; but there is nothing to lead us to suppose that this grey mud when it fell was even warm.

It has been suggested by some that this moist deposit was mud thrown out from the bottom of Rotomahana Lake; but it is difficult to conceive how, in that case, it should have overleapt a strip of country four or five miles wide, where there is nothing but dry sand, before it reached Wairoa; and I think that a more likely source for its origin is to be found in the sudden condensation of the front edge of the great vapour-and-dust cloud when it suddenly met the violent cold south-west gale which averted it from Rotorua and directed it towards the sea-coast, where it spread over the sky and caused the darkness that was experienced at Tauranga and all over the country to the eastward. The great volume of this dust-cloud was directed towards the East Cape, dropping over

the country in that direction a comparatively heavy deposit of brownish-black dust, so coarse as almost to be sand; while on its northern edge, as far east as Tauranga, the dust is of a light-grey colour and excessively fine in grain. A collection of all these different deposits has been obtained, and will be reported on as soon as the chemical analysis is complete. The impact of the moist deposit when it fell must have been very great, from the effects which it produced at Wairoa, where it appears to have attained its maximum thickness of about 12in. in open level places free from any influence that would cause it to drift; on the flat spur above the bridge at the outlet of Rotokakahi its depth was found to be 9in., and in the Tikitapu Bush 4in.; and from that point it gradually decreased towards the north. The action of rain upon this mud rapidly converts it into a semi-fluid condition, in which state it slides off the hill-slopes and fills the low grounds and watercourses; and where it has been thickly deposited it will thus be a constant source of danger for some time to come, but where only an inch or so in thickness it will, I believe, rapidly disappear, and, excepting that it may for a time deteriorate the pasture and destroy the existing vegetation, it will in the long-run be an advantageous addition to the light pumice-soils upon which it has been deposited, owing to its slightly absorbent properties. As for the light deposit of dust, which fell in a dry state, there is very little doubt that it will be all washed off into the soil with the first heavy rains that come. The distance to which this fine dust was carried was very great, exceeding at least 120 miles from the focus in a direction between north and east; and the time it remained suspended in the atmosphere was at least eighty-four hours, as we passed through it in the "Hinemoa" when crossing the Bay of Plenty on the Saturday afternoon, as a peculiar yellowish fog, charged with pungent acid vapour, and dust; and on the following afternoon we recognised the same fog-cloud still suspended in the atmosphere towards the north-east.

V. THE EVOLUTION OF STEAM.

The enormous volume of steam rising from the site of Rotomahana Lake gave rise to a pillar of cloud that is visible in all directions over the country, having a diameter about an eighth of a mile, and rising to a height of not less than 12,000ft. Its effect is most impressive, especially in the morning and evening, when it is lighted up with gorgeous tints by the slanting rays of the sun when it is below the horizon, and all the surrounding landscape is in twilight. Although this steam-cloud receives rapid additions in its lower part from successive explosions, these do not generate any rapid movement through the mass of this cloud, so that, if viewed from a distance, it appears to be almost solid and immovable, except the changes that are gradually effected upon its lower portion by the movements of the atmosphere.

VI. THE PROPAGATION OF THE EARTHQUAKE TREMORS.

Earthquakes are the usual results of the violent concussions attendant upon violent outburst, and they afford the only clue which we can possibly have as to the depth below the surface of the earth at which the volcanic energy has been exerted. Thus, if the earthquakes are felt with only slightly-decreased violence to great distances from the focus of disturbance, it would indicate that the disturbance is a deep-seated one. On the other hand, if the earthquakes, although extremely violent close to the focus, are only felt to a moderate distance, the conclusion to be drawn is that the forces at work are only superficial. All reports agree that at the Wairoa, about four miles distant, which is the nearest point to the eruption from which any persons have survived, the shocks of earthquake during the first phase were violent and continuous; whereas at Rotorua, twelve miles distant, they were comparatively slight. The great earthquake at the commencement of the second phase appears to have been felt with considerable violence at Rotorua, and distinctly arrested attention for a distance of at least from sixty to seventy miles, but does not appear to have done any damage.

During our visit the earthquake shocks in the vicinity of Rotomahana were still frequent and violent, but at Rotorua they were only experienced as gentle undulations; and I ascertained that they proceeded from the effects of the explosion from the Rotomahana fissure, and that the eruptions from the summit of Tarawera, which were clearly visible from Rotorua, did not produce the slightest apparent tremor at that distance. A few insignificant earthquake-rents were seen crossing the flats south of Kaitiriria, but only where there was a drop or unsupported bank.

VII. THE SOUNDS.

The sounds produced during the eruption must have been, from all accounts, appalling to those within a moderate distance. The crackling thunder produced by the electrical discharges, the terrific roaring of the high-pressure steam escaping through the volcanic vents, were combined with terrifying effects.

Much has been said about noises heard at Auckland, Wanganui, and other places. From the times mentioned, these appear to have been due to the reverberating reports accompanying the Tarawera outbreaks. Some of these noises may have been propagated through the atmosphere, and reflected to the earth from the under-surface of the stratiform cloud-sheets that were widely spread in various directions over the colony on that morning. Others, again, may have been propagated through the earth. But I have been informed that at the whaling settlement of Tawaite, on the east entrance of Tory Channel, from six p.m. up to about eight p.m. on the evening of the 9th (the night preceding the

eruption), loud booming reports were heard as if through the earth. As these reports were previous to any symptom of the loud disturbances at Tarawera, this suggests that they may have resulted from a slight movement along the great fault-lines that traverse the North and South Islands in a north-easterly direction; and, in this case, the immediate cause of the Tarawera outburst may be found in a local fracture resulting from such movement.

VIII. PREMONITORY SYMPTOMS.

The only premonitory symptoms of the coming outburst which have been described were an oscillation in the level of Tarawera and Rotorua Lakes, and the occurrence of earthquakes for some months past in that district, where, as a rule, earthquakes are rarely felt. But neither of these is a very characteristic incident, nor would it be safe on future occasions to base any expectation of an eruption on such phenomena alone. The increased activity of the geysers and hot-springs during the past season has also been advanced as having been a symptom of an approaching outbreak; but those who were most familiar with the district will agree that their variation was no greater than is usual under the influence of rapid changes of wind and atmospheric pressure.

The reports of sympathetic outbreaks in other places along the line of volcanic energy from White Island to Ruapehu appear to be quite unfounded. The outburst has shown conclusively that the springs at Rotorua and Rotomahana are quite independent of each other, and of those at other places, thus confirming the observations made by Von Hochstetter long ago, that all the various points at which thermal springs occur are situated round the margins of lakes formed by subsidence of circular areas, and are not connected by an underground system of gravitational drainage.

IX. CONCLUSION.

From the foregoing sketch of the character of the eruption, I think there can be little question that it is a purely hydrothermal phenomenon, but on a gigantic scale; that it is quite local and not of deep-seated origin; and that all danger is past for the present, so far as one can venture to form an opinion on such a subject. The extra activity of the *puias* which has been observed is no doubt owing to the heavy rains that, on the 9th, set in after the longest period of drought which has been experienced in that district for many years, and probably the frequent earthquakes which have of late agitated the ground have contributed to this activity by stirring up the sources of the water-supply, and facilitating the access of drainage-waters to the sources of the heat. But beyond what may be accounted for in this manner I believe there is no increased

disturbance at Rotorua, Wairakei, Taupo, and other places. The quiescent condition of Tongariro and Ngaurahoe was plainly shown by the manner in which we observed it to be enveloped in snow. As a rule, on the scoria cone of Ngaurahoe snow rarely lies, excepting in a few of the gullies, but melts almost as soon as it falls. On the morning of the 17th, however, the cone of Ngaurahoe was covered with a great mantle of snow; while the *puias* on Tongariro showed less than their usual amount of steam escaping. The only fresh activity which may be reasonably expected is that which I anticipate when sufficient rain has fallen to cause the overflow of Okaro Lake into the south end of the great fissure, as its former drainage outlet to the Rotomahana Lake appears to me to be completely filled up. If this should occur and a fresh explosion takes place in consequence, it will be comparatively moderate in its effects, as, unlike Rotomahana, the soft, incoherent pumice-deposits between the fissure and Okaro Lake are not sealed down by an enormous weight of siliceous sinter.

For some time to come great variations must be expected in the activity of the newly-formed *puias* according to the manner in which changes occur in the atmospheric pressure; but, unless it can be shown that any local change in the barometer is experienced which is not shared by the surrounding district, the barometer affords no indication as to whether an eruption is or is not imminent. One of the most unfortunate results of the eruption, in addition to the disastrous loss of life and the destruction of the country, is the disturbance of the sense of security which has grown up amongst those residing at the Hot Springs; and I believe that many persons are so thoroughly shaken by the horrors experienced on the morning of the 10th that they will not recover their equanimity until they have been for some time resident away from the sounds, smells, and shocks that characterize the district. An analytical report by Mr. Skey on the nature of the volcanic deposits is appended, and a series of photographic views (thirty-seven in number) will be furnished as soon as printed.

APPENDIX.

ANALYSES of Fine-grained Dust from the Tarawera Eruption of 10th June, 1886. (Lab. No. 4324.)

Two of these only have, as yet, been fully examined: No. 1, Tauranga, and No. 2, Hicks Bay. Neither of these samples was distinctly acid; No. 1, indeed, was feebly alkaline. No. 1 is grey; No. 2 is pale brown. The subjoined results show a remarkable uniformity in the character of these two samples, although collected from localities miles apart.

Analyses.

	Tauranga.	Hicks Bay.
Silica	60·74	59·37
Iron oxides	11·58	10·18
Alumina	16·09	17·96
Manganese	Trace	Traces
Lime..	5·69	5·98
Magnesia	·96	1·19
Phosphoric acid	Trace	Traces
Water	2·26	2·21
Salts soluble in water	Trace	Traces
Organic matter	Trace	·99
Alkalies	2·68	2·12
	100·00	100·00

It may be mentioned that the hardened mud (No. 5) from Wairoa afforded 62·98 per cent. of silica. Both are fine-grained, but No. 1, from Tauranga, is the finer-grained of the two. Free quartz is present in both, and, as owing to their fineness it is impossible to separate it, I cannot yet determine how much of the silica in the analyses is combined, and so I am unable to affirm exactly as to the nature of the silicate or silicates present in these dusts. If 20 per cent. of free quartz be assumed to be present, the proportion of combined silica is about 50 per cent., which fixes the major part of the compounds as *unisilicates*. These dusts, though of much the same nature, behave in a remarkably dissimilar manner when moistened. No. 1 (Tauranga) is extremely absorbent of water, and, even if previously caked, speedily falls therein to a mobile sand; No. 2 (Hicks Bay dust), on the other hand, seems to repel water, and, even when wetted partially, clogs to an adhesive mud. From the few experiments which I have made, I feel pretty certain that the reason of this dissimilarity is simply this: The dust No. 2 has the oils of a partial combustion of organic matter condensed upon it. Possibly these are the organic matters in the analysis. I base this opinion upon the fact that, when heated to redness a short time, this dust is just as absorbent of water as the other; while, if merely heated to 212° Fahr., this change in character does not obtain. In this way I would also explain the pasty condition which the Hicks Bay dust assumes when kneaded with a small quantity of water. It then becomes adhesive, from which it has been supposed to contain a notable proportion of clay, which it certainly does not. Washed with water, only 1·2 per cent. of material was obtained, which had not any tendency to keep in "suspension," and this proved devoid of plastic properties when collected. The lumpy and semi-plastic character this dust assumes in water is due not to the presence of clay, but to a surface-repulsion of its particles.

The Tauranga dust affords 35·8 per cent. of substances capable of prolonged suspension in still water. Yet it is not adhesive or plastic; this suspended matter being fine grains of silicates and quartz, which hydrate on their superficies, and on these only.

In order to ascertain the degree to which these two dusts are likely to be affected by atmospheric agencies they were digested for one hour with hydrochloric acid diluted with four volumes of water.

Appended are the results of the approximate analysis of the matters which, in each case, were dissolved, as stated, centesimally:—

	1.	2.
Silica (1)	·46	·61
Iron and alumina	6·42	7·02
Lime	1·84	2·06
Magnesia	·32	·26
Alkalies (2)	·48	·39
Phosphoric acid	Trace	Traces
Total dissolved ..	9·52	10·34

(1) Most of the silica liberated was, it appears, kept in the insoluble form.
(2) Was especially examined for the quantity of potash dissolved from the dust by the same process; only ·24 per cent. of potash was obtained.

These results, as compared with the result of the approximate analysis of soil by the same method as above, show that both these dusts are much inferior to even very indifferent soils. For clay lands they might be of service mechanically.

APPENDIX.

INDEX TO FOSSILIFEROUS LOCALITIES IN NEW ZEALAND.

THE following is a list of the numbers which distinguish the fossils in the Colonial Museum from each locality, and by which they are referred to in the Geological Reports, together with the formation in which the locality is placed according to the classification at present adopted in the work of the Geological Survey.

The year in which each collection was made is also given, to assist reference to the reports in which the localities are described, and the name of the collector is indicated as follows: H., Hector; Ha., Von Haast; Ht., Hutton; Cr., Crawford; C., Cox; M., McKay; B., Buchanan; P., Park; and a few others mentioned by name.

There are in addition many fossiliferous localities the collections from which, having been made during the provincial surveys of Canterbury, by Von Haast, and of Otago, by Hector, are preserved in the Christchurch and Dunedin Museums, and are not included in this list.

JAMES HECTOR,
Director.

30th June, 1887.

TABLE OF FOSSILIFEROUS FORMATIONS IN NEW ZEALAND.

I. Recent—
- *a.* Moa beds.
- *b.* Alluvia.
- *c.* Volcanic.
- *d.* Shingle-plains.

II. Pliocene—
- *a.* Shingle-plains.
- *b.* Pumice-sands.
- *c.* Lignite-beds.
- *d.* Kereru beds.

III. Upper Miocene—
- *a.* Te Aute beds.
- *b.* Awatere beds.

IV. Lower Miocene—
- *a.* Ross beds.
- *b.* Mangapakeha beds.
- *c.* Pareora beds.

V. Upper Eocene—
- *a.* Mount Brown beds.
- *b.* Oamaru beds.
- *c.* Nummulitic beds.

VI. Cretaceo-tertiary—
- *a.* Grey-marls.
- *b.* Ototara stone.
- *c.* Fucoidal greensand.
- *d.* Amuri limestone.

VI. Cretaceo-tertiary—*continued.*
- *e.* Island sandstone.
- *f.* COAL FORMATION OF NEW ZEALAND.
- *g.* Black-grit.
- *h.* Propylite breccias.
- *i.* Conglomerate.

VII. Neocomian—
- *a.* Conglomerates with coal.
- *b.* Porphyries.
- *c.* Greensands.

VIII. Jurassic—
- *a.* Mataura beds.
- *b.* Putataka beds.
- *c.* Flag Hill beds.

IX. Liassic—
- *a.* Catlin's River beds.
- *b.* Bastion beds.

X. Rhœtic and Triassic—
- *a.* Otapiri beds.
- *b.* Wairoa beds.

XI. Permian—
- *a.* Oreti beds.
  Great conglomerate.
  Great sandstones.
- *b.* Mount Potts bed.
  Kaihiku beds.
  Glossopteris beds.
- *c.* Conglomerates.
  Red sandstones.

[*Upper Carboniferous not yet identified.*]

XII. Lower Carboniferous—
- *a.* Maitai slates.
- *b.* Te Anau beds.

XIII. Lower Devonian—
Reefton beds.

XIV. Upper Silurian—
- *a.* Baton River slates.
- *b.* Limestones.
- *c.* Serpentinous slates.

XV. Lower Silurian—
- *a.* Graptolite slates.
- *b.* Marbles.
- *c.* Hornblende rocks.

	Locality.	Formation
1.	Fern beds, Kais Hill, Amuri Bluff, M., 1876	VIII*a*.
2.	Calcareous conglomerate, East Wing, Amuri Bluff, M., 1876	VII.
3.	Belemnite bed, East Wing, Amuri Bluff, M., 1876	VII.
4.	Trigonia beds, East Wing, Amuri Bluff, M., 1876	VII.
5.	Nummulite beds, Whareama, H., 1867	V*c*.
6.	Aporrhais beds, East Wing, Amuri Bluff, M., 1876	VII.
7.	Greensands, below black grit, East Wing, Amuri Bluff, M., 1876	VII.
8.	Black-grit, East Wing, Amuri Bluff, M., 1876	VI*g*.
9.	Boulder sands, East Wing, Amuri Bluff, M., 1876	VI*f*.
10.	Concretionary greensand, East Wing, Amuri Bluff, M., 1876	VI*e*.
11.	Teredo limestone, East Wing, Amuri Bluff, M., 1876	VI*e*.
12.	Amuri limestone, Amuri Bluff, M., 1876	VI*d*.
13.	Amuri group, West Wing, Amuri Bluff, M., 1876	VII.
14.	Oaro Creek, Amuri Bluff, M., 1876	VI*e*, *f*.
15.	Old diggings (Hughie's), Buller River, Nelson, H., 1873; M., 1874	VIII*a*.
16.	Lower Kaihiku Gorge, Otago (plants), M., 1873	XI*b*.
17.	Lower gorge of Pureroa River, Otago, M., 1873	XI*b*.
18.	Lower gorge of Pureroa River, Otago, M., 1873	XI*b*.
19.	Old Mill, Owake Creek, Catlin's River, Otago, M., 1873	IX*a*.
20.	Mouth of Catlin's River, Otago, M., 1873	IX*a*.
21.	Pholadomya Point, Catlin's River, Otago, H., 1865	IX*a*.
22.	Greensands, Green Island, Otago, H., 1865; M., 1873	VI*e*.
23.	Selwyn River, Canterbury, Ha., 1871	VI*e*, *f*.
24.	Amuri Bluff, B., 1867	VII.
25.	Amuri Bluff, Ha., 1869	VI., VII.
26.	Callaghan's Hill, Westland, H., 1866	III*d*.
27.	Ten-mile Creek, north of Cobden, Nelson, M., 1874	VI*f*.
28.	Welshman's Terrace, Brighton, west coast of Nelson, M., 1874	VI*f*.

	Locality.	Formation.
29.	Brunner Mine, Grey River, Westland, H., 1870; M., 1873 ..	VI*f, g.*
30.	Morley Creek, Southland (Unio beds), H., 1869	VI*g.*
31.	Island sandstone, Woodpecker Bay, Brighton, west coast of Nelson, M., 1874	VI*f.*
32.	Nine-mile Bluff, Cobden, west coast of Nelson, H., 1866; M., 1873	VI*f.*
33.	Above Island sandstone, Woodpecker Bay, Brighton, west coast of Nelson, M., 1874	VI*e.*
34.	Inland of White Rock Point, Mokihinui River, Nelson, M., 1874	VI*e.*
35.	Cobden limestone, Greymouth, Westland, H., 1866	VI*d.*
36.	Conway River, Marlborough, Ha., 1869	VI*d.*
37.	Castlepoint, east coast of Wellington, H., 1867	III*b.*
38.	Rainy Creek, Reefton, M., 1874	VI*f.*
39.	Whangape Lake, Auckland, Ht., 1867	VI*d.*
40.	Tokomairiro limestone, Waihola Gorge, Otago, B., 1869; M., 1873	VI*b.*
41.	Black limestone, Tokomairiro, Otago, H., 1865	VI*e.*
42.	Baton River, Nelson (quartz grit), H., 1867	VI*f.*
43.	Raglan, west coast of Auckland, H., 1866	VI.
44.	Mokihinui River, Nelson, M., 1874	IV*b.*
45.	St. Kilda, Brighton, west coast of Nelson, M., 1874	VI*f.*
46.	Seal Rock, Brighton, west coast of Nelson, H., 1870	VI*b.*
47.	The Castles, Slate River, Nelson, C., 1881	V*a, b.*
48.	Inangahua Junction, Buller River, Nelson, H., 1873; M., 1874	VI*f.*
49.	Inangahua Ferry, Reefton, and Westport Road, Nelson, H., 1873; M., 1874	VI*e.*
50.	Christie's, Inangahua, Nelson, H. and M., 1874	VI*e.*
51.	Aotea, west coast of Auckland, H., 1866	VI*d.*
52.	White Cliffs, Taranaki, H., 1865 and 1878	VI*a.*
53.	Caversham, Dunedin, Otago, H., 1869	VI*a.*
54.	Cape Turnagain, south coast of Napier, M., 1875	II*a.*
55.	White Rock Point, north of Mokihinui River, Nelson, M., 1874	VI*a.*
56.	Coal-beds, Kokohu River, South Canterbury, Monro, 1869 ..	VI*f.*
57.	Shakespeare Bay and Elevation, near Picton, Marlborough, H., 1865; Ht., 1872; M., 1874	VI*a.*
58.	Point Elizabeth, Cobden, west coast of Nelson, H., 1866; M., 1874	VI*b.*
59.	Darkie Terrace, Cobden, west coast of Nelson, H., 1866; M., 1873	VI*b.*
60.	Poverty Bay, Auckland, H. and M., 1874	VI*a.*
61.	Nummulitic limestone, Greymouth, H. and M., 1873	V*c.*
62.	Railway cutting, Jenkins's Hill, Nelson, M., 1874	VI*d.*
63.	Lake Wakatipu, Otago, H., 1874	VI*e.*
64.	Cobden limestone, Greymouth, Westland, H., 1869; M., 1873 ..	VI*b.*
65.	Bryant's, near Gisborne, Poverty Bay, H. and M., 1874 ..	VI*a.*
66.	Mount Brown, Waipara, Canterbury, H., 1867; M., 1874 ..	V*a.*
67.	Saurian beds, Trelissick section, Broken River, Canterbury, Enys and H., 1872; M., 1874	VI*f.*
68.	Akuakua, east coast of Auckland (Venus beds), H. and M., 1874	VI*a.*
69.	Akuakua, east coast of Auckland (lower beds, Tertiary), H. and M., 1874	V*b.*
70.	Akuakua, east coast of Auckland (upper beds, Tertiary), H. and M., 1874	IV*b.*
71.	Grey-marls, Weka Pass, Canterbury, H., 1867; M., 1874 ..	VI*a.*
72.	Te Wharepunga, east coast of Auckland, H. and M., 1874 ..	VI*d.*
73.	Limestone, Waipiro Bay, east coast of Auckland, M., 1874 ..	VI*d.*
74.	Weka Pass calcareous greensands, Weka Pass, Canterbury, H., 1867; Ha., 1869; M., 1874	VI*b.*
75.	Kaihiku Gorge, Otago, B., 1869	XI.
76.	Whangaroa, North of Auckland, H. and M., 1866	VI*f.*
77.	Cape Kidnappers, Napier, H., 1866; M., 1875	II*c.*
78.	Cape Kidnappers, Napier, M., 1875	I*d.*
79.	Cape Kidnappers, Napier, M., 1875	II*a.*
80.	Scinde Island limestone, Napier, H., 1866	II*a.*
81.	Castlepoint, east coast of Wellington, M., 1875	III*b.*
82.	Hakarimata Range, Waikato, Auckland, C. and M., 1875 ..	X*b.*
83.	Waimarama, Napier, M., 1875	VII.

	Locality.	Formation.
84.	Paonui Point, Pourerere, Napier, M., 1875	VII.
85.	Mouth of Maungakuri River, Napier, M., 1875	VII.
86.	North bank of the Pourerere River, Napier, M., 1875	V*c*.
87.	Nummulitic limestone, Paonui Point, Napier, M., 1875 ..	V*c*.
88.	Roparua and Tuparoa, east coast of Auckland, H. and M., 1874	VII.
89.	Awanui, east coast of Auckland, M., 1874	VII.
90.	McDonald's Section, Poverty Bay, H. and M., 1874	VI*d*.
91.	Lower part of Shakespeare Cliff, Wanganui, B , 1866	III*a*.
92.	Upper part of Shakespeare Cliff, Wanganui, B., 1866	II*c*.
93.	Taipos, east coast of Wellington, H., 1866	IV*b*.
94.	Taerua River, Wairarapa, Wellington, M., 1875	III*b*.
95.	Makara Valley, Wellington, M., 1876	III*b*. (?)
96.	Raglan, plastic clays, C. and M., 1875	II*b*.
97.	Limestone, five miles north of Raglan, west coast of Auckland, C. and M., 1875..	V*b*.
98.	Brown sandstone and flaggy limestone, Raglan, west coast of Auckland, C. and M., 1875	VI*b*.
99.	Leda marls, Raglan, west coast of Auckland, C. and M., 1875 ..	VI*d*.
100.	Leda marls, Miranda Redoubt, Auckland, C. and M., 1875 ..	VI*d*.
101.	Mercer, Waikato River, C. and M., 1875	VI*d*.
102.	Smyth River, Lake Heron, Canterbury, Ha., 1872	VI*e*.
103.	Cave Creek, Mount Somers, Canterbury, Ha., 1872	V*a*.
104.	Fossil Point, Ashburton River, Canterbury, Ha., 1872 ..	V*a*.
105.	St. Peter's Mount, Whangaroa, North of Auckland (plants), H., 1866	III*d*.
106.	Whangaroa, North of Auckland, M., 1875	VII.
107.	Kaeo River, Whangaroa, North of Auckland, M., 1875 ..	VI*e*.
108.	Ruamahunga River, Masterton, B., 1872	III*d*.
109.	Manawatu Gorge (lower end), B., 1872	II*b*.
110.	Culverden, Nelson, Ha., 1869	V*a*.
111.	Whangara, Poverty Bay, east coast of Auckland, H. and M., 1874	VI*e*.
112.	Coralline limestone, Raglan, C. and M., 1875	VI*c*.
113.	Pourerere River, Napier, M., 1875	IV*b*.
114.	Pourerere River, Napier, M., 1875	VII.
115.	Flanks of Castle Range, west of Pourerere, Napier, M., 1875 ..	V*c*.
116.	Waimarama, Napier, Enys, 1874; M., 1875	VI*a*.
117.	Mangapakeha Valley, east coast of Wellington, H., 1866; M., 1875	IV*a*.
118.	Akiteo River, east coast of Wellington, H., 1873; Enys, 1874 ..	VII.
119.	Akiteo River, east coast of Wellington, H., 1873	I*c*.
120.	Maraetotara River, Napier (Young Tertiary), M., 1875 ..	II*b*.
121.	Korakonui, east coast of Wellington, H., 1866	IV*b*.
122.	Waimarama, coast of Napier (Scinde Island beds), M., 1875 ..	II*b*.
123.	Kupakupa Coal-mine, Waikato, Auckland (plants), C. and M., 1875	VI*g*.
124.	Black marls, Mount Rochfort, M., 1874	VI*e*.
125.	Fox River, Brighton, west coast of Nelson, M., 1874	IV*b*.
126.	Awatere River, Marlborough, B., 1867	III*d*.
127.	Awatere Point, Awanui, east coast of Auckland, M., 1874 ..	VII.
128.	Mount Arthur, Nelson, H., 1867; M., 1879	XIV*a*.
129.	Rainy Creek, Reefton (Devonian), H. and M., 1874	XIII.
130.	Lankie's Gully, Reefton, H. and M., 1874	XIII.
131.	Lower Kaihiku Gorge, Otago, M., 1873	XI.
132.	Wyndham River, Otago, B., 1866	IX*a*.
133.	Nugget Point, Otago, H., 1869; M., 1873	X*a*.
134.	Wiltshire Beach, Molyneux Bay, Otago, M., 1873	XI*a*.
135.	Upper Purerua Gorge, M., 1873	X*c*.
136.	Mount Potts, Rangitata River, Canterbury, Ha., 1872 ..	XI*b*.
137.	Benmore, Hokonui District, Southland, H., 1869	X*a*, *b*.
138.	Moonlight Range, Southland, Ht., 1872	X*b*.
139.	Richmond Hill, Nelson, H., 1866	X*b*.
140.	Wairoa Gorge, Nelson, H., 1866	X*b*.

	Locality.	Formation.
141.	Wairoa Gorge, Nelson, M., 1874	X*b*.
142.	Aniseed Valley, Nelson (Monotis beds), H., 1866	X*b*.
143.	Dun Mountain, Nelson, H., 1866; M., 1878	XII*a*.
144.	Morley Creek, Southland, H., 1869	IX*a*.
145.	Otapiri Creek, Southland, H., 1869	IX*a*.
146.	Tautuku, Otago, H., 1869	IX*a*.
147.	Between Nugget Point and Cannibal Bay, Otago, M., 1873 ..	IX*a*.
148.	Mainland opposite Bloody Jack's Island, Otago, M., 1873 ..	IX*a*.
149.	McKay's Creek, Middle Waipara, Canterbury, M., 1874 ..	VI*f*.
150.	Grey-marls, Heathstock, Upper Waipara, Canterbury, M., 1874	VI*a*.
151.	Okuku Range, west of Mount Grey, Canterbury, M., 1874 ..	X*b*.
152.	Weka Creek, Weka Pass, Canterbury, M., 1874	VI*f*.
153.	Callaghan's Hill, Westland, C. and M., 1875	III*d*.
154.	Kanieri River, Westland, C. and M., 1875	IV*b*.
155.	Ross, Westland, C. and M., 1875	III*c*.
156.	Abbey Rocks, Paringa District, Westland, C. and M., 1876 ..	VI*e*.
157.	Kaikoura Peninsula, Marlborough, M., 1876	VI*f*.
158.	Amuri Bluff Hill, M., 1876	II*a*.
159.	Mount Grey Downs, Canterbury, M., 1874	IV*b*.
160.	Grey Stream, Mount Grey, Canterbury, M., 1874	IV*b*.
161.	Nugget Point, Otago, B., 1866	X*a*.
162.	Weka Pass Stone, Kokohu River, South Canterbury, M., 1876 ..	VI*b*.
163.	Greensands overlying coal, Kokohu River, S. Canterbury, M., 1876	VI*e*.
164.	Coal-beds, Kokohu River, South Canterbury, M., 1876 ..	VI*f*.
165.	White Rock River, Upper Pareora River, Canterbury, M., 1876	IV*b*.
166.	Lower Gorge, Pareora River, Canterbury, M., 1876	IV*b*.
167.	Lower Gorge, Pareora River (coal-beds), M., 1876; Enys, 1879 ..	VI*f*.
168.	Otepopo River, Oamaru, Otago, M., 1876	VI*e*.
169.	Kakanui limestone, Kakanui, Otago, M., 1876	V*b*.
170.	Awamoa Creek, Oamaru, Otago, M., 1876	IV*b*.
171.	Cape Wanbrow to breakwater, Oamaru, Otago, M., 1876 ..	VI*e*.
172.	Hutchinson's Quarry, Oamaru, M., 1876	V*b*.
173.	Limekiln Gully, Oamaru, Otago, M., 1876	V*b*.
174.	Devil's Bridge, Oamaru Creek, Otago, M., 1876	V*b*.
175.	One mile south of Devil's Bridge, Oamaru Creek, Oamaru, M., 1876	IV*b*.
176.	Black Point, Waitaki River, Otago, M., 1876	VI*e*, *f*.
177.	Maerewhenua gold-workings, Otago, M., 1876	VI*f*.
178.	Phorus beds, Maeraewhenua, Waitaki, Otago, M., 1876 ..	VI*a*.
179.	Maerewhenua limestone, Waitaki, Otago, M., 1876	VI*b*.
180.	Dorset's, Forty-mile Bush, Wellington, M., 1877	III*b*.
181.	Manawatu Gorge, Wellington (upper end), M., 1877	III*b*.
182.	Manawatu Gorge, Wellington (lower end), M., 1877	II*b*.
183.	Norsewood, Seventy-mile Bush, Napier, M., 1877	II*b*.
184.	Porangahau Creek, Ruataniwha Plains, Napier, M., 1877 ..	II.
185.	Johnston's, Ruataniwha Plains, Napier (shell limestone), M., 1877	II*c*.
186.	Waipawa River, Napier, M., 1877	VI*d*.
187.	Stokes's Run, Te Aute Hills, Napier (shell limestone), M., 1877	III*b*.
188.	Kereru, inland from Napier (Rotella beds), M., 1877	II*c*.
189.	Kereru, inland from Napier (limestone), M., 1877	III*b*.
190.	Kereru, inland from Napier (lower beds), M., 1877	III*b*.
191.	Shrimpton's, Ngarurora River, Napier (upper), M., 1877 ..	II*a*.
192.	Shrimpton's, Ngarurora River, Napier (middle), M., 1877 ..	II*a*.
193.	Shrimpton's, Ngarurora River, Napier (lower), M., 1877 ..	II*b*.
194.	Scinde Island, Napier, M., 1877	II*c*.
195.	Plant-beds, Eighty-eight Valley, M., 1878	IX*a*.
196.	Trigonia beds, Eighty-eight Valley, M., 1878	IX*a*.
197.	Spiriferina beds, Eighty-eight Valley, M., 1878	IX*a*.
198.	Hokianga, Auckland (Tertiary beds), H., 1874	IV*b*.
199.	Morrison's, north of Auckland (coal-beds), H., 1874	VI*e*, *f*.
200.	Evans's Bay, Wellington Harbour, M., 1876	I*c*.
201.	Taipos, east coast of Wellington, M., 1875	IV*b*.
202.	Turanganui, Poverty Bay, Gisborne (No. 1), H. and M., 1874 ..	I*c*.
203.	Turanganui, Poverty Bay, hill east of river (No. 2), H. and M., 1874	II*a*.

	Locality.	Formation.
204.	Turanganui, Poverty Bay, McDonald's section (No. 3), H. and M., 1874	II*b*.
205.	Durie's Hill, Wanganui, Kirk, 1875	II*b*.
206.	Shakespeare Cliff, Wanganui (upper part), Kirk, 1875 ..	II*c*.
207.	Railway cutting, ten miles from Wanganui, Kirk, 1875 ..	II*a*.
208.	Lower part of Shakespeare Cliff, Wanganui, Kirk, 1875 ..	III*a*.
209.	Waitotara, west coast of Wellington, H., 1870	III*d*.
210.	Mount Reilly, New River District, Westland, M., 1874 ..	III*c*.
211.	New River, Westland (Tertiary), H., 1869	III*d*.
212.	Ormond, Poverty Bay, M., 1874	II*a*.
213.	Awamoa, Oamaru, Otago, Traill, 1865	IV*b*.
214.	Hampden, Otago, Traill, 1865	IV*b*.
215.	Sherry River, Nelson, H., 1867	VI*e*.
216.	Mount Caverhill, Nelson, Ha., 1869	IV*b*.
217.	Cape Kidnappers and Te Aute Hills, H., 1867 ..	II*a* to III*b*.
218.	Motunau, Canterbury, B., 1867	IV*b*.
219.	Motunau, Canterbury, B., 1867	II*a*.
220.	Petane, Hawke's Bay, Napier (shell limestone), C., 1876 ..	II*a*.
221.	Petane, Hawke's Bay, Napier (sandy clays), C., 1876	II*b*.
222.	Watchman's Island, Napier Harbour, Williams, 1878 ..	II*c*.
223.	North side of Tokomaru Bay, M., 1874	IV*b*.
224.	Kakanui River, Oamaru, Otago, M., 1876	VI*e*.
225.	Gilligan's, Westland, H., 1869	III*d*.
226.	Upper Trelissick, Enys and H., 1872	IV*b*.
227.	Kanieri, Westland, H., 1869	IV*b*.
228.	Lower gorge of the Waipara, Canterbury, H., 1867	IV*b*.
229.	Manawatu Gorge, B., 1874	II*b*.
230.	Kaipuki Cliffs, Nelson, H., 1867	V*a*.
231.	McLean's, Ngaruroro River, Napier, H., 1871	II*b*.
232.	Hurunui Mound, Nelson, Ha., 1869	IV*b*.
233.	Waikare, Canterbury, H., 1872	IV*b*.
234.	Lake Lyndon, West Coast Road, Canterbury, H., 1872 ..	IV*b*.
235.	Plant-beds, road-cutting, Thomas River, Trelissick Basin, M., 1874	III.
236.	Pareora beds, Thomas and Porter Rivers, Trelissick Basin, M., 1879	IV*b*.
237.	Upper part of Mount Brown limestone, Trelissick Basin, M., 1879	V*a*.
238.	Mount Brown limestone, Coleridge Creek, Trelissick Basin, Enys, 1866, 1879	V*a*.
239.	Fan-coral bed, Porter and Thomas Rivers, Trelissick Basin, M., 1879	V*c*.
240.	Below Weka Pass stone, Porter River, Trelissick Basin, M., 1879	VI*b*.
241.	Tufaceous greensands, Whitewater Creek, Trelissick Basin, M., 1879	VI*e*.
242.	Weka Pass stone, Trelissick Basin, Enys, 1866, 1879	VI*b*.
243.	Fan-coral bed, Trelissick Basin, Enys, 1866, 1879	V*c*.
244.	Pareora beds, Trelissick Basin, Enys, 1866, 1879	IV*b*.
245.	Castle Rock, Southland, M., 1878	IV*b*.
246.	Cape Rodney, Auckland, H., 1866; C., 1879	IV*b*.
247.	Forest Hill Range, Southland, M., 1878	V*a*.
248.	Waitaki River, Otago, H., 1865	V*c*.
249.	Duncan's, east coast of Auckland, H. and M., 1874	IV*b*.
250.	Aohanga Falls, Akateo River, east coast of Wellington, H., 1873	IV*b*.
251.	Wharekauri, Traill, 1874	V*c*.
252.	Otakaika, Traill, 1874	V*c*.
253.	Pakeuri, Traill, 1874	V*c*.
254.	Awamoa, Traill, 1874	IV*b*.
255.	Cape Hills, Oamaru, Traill, 1874	V*b*.
256.	Grey-marls, Otapiri Creek, Southland, M., 1878	VI*a*.
257.	Kawau Island, H., 1866	IV*b*.
258.	Waimea Plains, Southland (limestone), H., 1869	V*a*.
259.	Parakino and Upper Wanganui Rivers, Cr., 1862	III., IV.
260.	Hautapu Falls, Rangitikei River, H., 1870	III.
261.	Tataka River, Nelson, H., 1868	V*a*.

	Locality.	Formation.
262.	Orepuki, Southland, H., 1869	V*b*.
263.	Hicks Bay, Auckland, H., 1874	IV*b*.
264.	Flaxbourne, Marlborough, M., 1876	VI*f*.
265.	Flaxbourne, Marlborough, M., 1876	III*d*.
266.	Point Elizabeth, Cobden, Nelson, H.	VI*b*.
267.	Waikato Heads, C., 1876	VIII*b*.
268.	Aotea sandstone, between Raglan and Kupakupa, Waikato, C., 1876	VI*b*.
269.	Limestone, between Raglan and Kupakupa, Waikato, C., 1876	VI*b*.
270.	Parua Bay, Whangarei, Auckland, C., 1876	VI*f*.
271.	Walton's Coal-mine, Whangarei, Auckland, H., 1865	VI*e*.
272.	Waikawau Creek, Waikato, Auckland, C., 1876	VI*a*.
273.	Whangape Lake, Ht., 1866..	VI*d*.
274.	One mile below Lyell, Buller River, Nelson, H., 1869 ..	VI*f*.
275.	Grey-marls, Weka Pass stone, and greensand conglomerate, east wing Amuri Bluff, M., 1876	VI*a*, *b*.
276.	Kawhia Harbour, west coast of Auckland, H., 1866	VIII*b*.
277.	Bobbie's Creek, Waipara District, Canterbury, H., 1867 ..	VI*f*.
278.	Source of the Mokihinui River, Nelson, H., 1867	VI*e*.
279.	Whangarei and Kawakawa, Auckland, H., 1866	VI*f*.
280.	Measley Beach, Otago, H., 1869	VI*f*, *e*.
281.	Between Ngakawau and Mokihinui Rivers, Buller District, H., 1871	VI*f*.
282.	Whangarei, Auckland, C., 1867	VI*f*.
283, 275.	Tiger Hill, Whangarei, Auckland, H., 1867	VI*f*.
284.	Morrison's District, North of Auckland, H., 1874	VI*e*.
285.	Grey-marls, Hawke's Bay, northern district, C., 1876.. ..	VI*a*.
286.	Cobden limestone, Marsden Road, Greymouth, M., 1873 ..	VI*b*.
287.	Tokomaru Bay, east coast of Auckland, M., 1874	VI*a*.
288.	Waireka Valley, Oamaru, Otago, M., 1876	VI*d*.
289.	Port Waikato, Auckland, C., 1876	VIII*b*.
290.	Marsden, New River District, Westland, M., 1873	V*c*.
291.	Maitai formation, Westland, M., 1875	XII*a*.
292.	Great Barrier Island, Ht., 1866	XIV*a*.
293.	Hapuka River, Looker-on Mountains, Marlborough, M., 1876 ..	VI*e*, *f*.
294.	Kaikoura Peninsula, Marlborough, M., 1876	VI*e*.
295.	Saurian beds, Heathstock Junction, Upper Waipara, M., 1874	VI*f*.
296.	Fossil Point, Cape Farewell, Nelson, H., 1868	V*a*.
297.	Orakei Bay, Auckland, H., 1866	VI*a*.
298.	Surveyors' Gully, Malvern Hills, Canterbury	VI*f*.
299.	Breakwater, Oamaru, Otago, M., 1876	I*c*.
300.		
301.	Coral-beds, Waikawau Creek, Waikato, Auckland, C., 1876 ..	VI*a*.
302.	Tata Island, Nelson, H., 1868	III.
303.	Clifton, Nelson, H., 1868	III.
304.	Culverden, Nelson, M., 1874	V*a*.
305.	Black-birch Creek, Nelson, Ha., 1869	V*a*.
306.	Marble Point, Waiau-ua River, Nelson, Ha., 1869	V*a*.
307.	Grey-marls, Cuff's Oil-springs, Poverty Bay, Auckland, H. and M., 1874	VI*a*.
308.	Oamaru, Otago, H., 1876	V*b*.
309.	Caversham, Dunedin, Otago, M., 1876	VI*a*.
310.	Interbedded with volcanic rocks, Oamaru Creek, Oamaru, M., 1876	V*c*.
311.	Curiosity Shop, Rakaia River, Canterbury, M., 1879	V*a*.
312.	South-west side of Oamaru Cape, Otago, M., 1876	V*b*.
313.	Dean's, Waipara River, Canterbury, H., 1872	V*a*.
314.	Cape Campbell, M., 1876	VII.
315.		
316.		
317.	Te Aro, Wellington	I*c*.
318.	Wairoa Gorge (Tertiary beds), M., 1878	IV*b*.
319.	Port Hills, Nelson, M., 1874	IV*b*.

	Locality.	Formation.
320.	Shag Point, Otago (shells), H., 1865	VI*f*.
321.	Waiau-ua River, Marlborough, B., 1867	VI*d*.
322.	Below flaggy limestone, Waikato Heads, C., 1877	VI*c*.
323.	Cardita beds, Waikawau Creek, Waikato, C., 1877	VI*a*.
324.	Marls, Baton River, Nelson, H., 1868	VI*e*.
325.	Red Cliff, Rakaia River, Canterbury, M., 1874	III*d*.
326.	Red Cliff, Rakaia River, Canterbury, M., 1874	V., VI.
327.	Awamoa Bridge, Oamaru, South Road, M., 1876	V*b*.
328.	Cook's Cove, Tolago Bay, east coast of Auckland, M., 1874 ..	IV*b*.
329.	Pomahaka River, Otago, H., 1869	IV*b*.
330.	Ngaruroro Gorge, Napier, M., 1877	III*c*.
331.	Dunedin Harbour	I*c*.
332.	Inoceramus beds, Makarewa, Hokonui Hills, Southland, C. and M., 1877	VIII*b*.
333.	Avicula beds, Flag Hill, Hokonui District, Southland, C. and M., 1877	VIII*b*.
334.	Astarte beds, lower end of Otapiri Gorge, Southland, C. and M., 1877	VIII*b*.
335.	Astarte beds, road-cutting, north side of Peel Hill, C. and M., 1877	VIII*b*.
336.	Astarte beds, top of Flag Hill, C. and M., 1877	VIII*b*.
337.	Highest Spirifer bed, Conical Hill, Otapiri Gorge, M., 1878 ..	VIII*b*.
338.	Highest Spirifer bed, table-land above Tree Bluff, Otapiri Gorge, M., 1878	VIII*b*.
339.	Highest Spirifer bed, north face of Flag Hill, M., 1878 ..	VIII*b*.
340.	Highest Spirifer bed, Upper Lora, behind Taylor's Station, M., 1878	VIII*b*.
341.	Lower Belemnite beds, north face of Flag Hill, M., 1878 ..	VIII*b*.
342.	Little Spirifer grit, north face of Flag Hill, M., 1878	VIII*c*.
343.	Upper Plagiostoma bed, west face of Flag Hill, M., 1878 ..	IX*a*.
344.	Upper Plagiostoma bed, north face of Flag Hill, M., 1878 ..	IX*a*.
345.	Upper Plagiostoma bed, west face of Bastion Hill, M., 1878 ..	IX*a*.
346.	Saddle between Taylor's Creek and Lora Station, M., 1878 ..	IX*a*.
347.	Upper Ammonite bed, west face of Flag Hill, M., 1878 ..	IX*a*.
348.	Higher part of Lower Plagiostoma bed, M., 1878	IX*a*.
349.	Lower part of Lower Plagiostoma bed, M., 1878	IX*a*.
350.	Between lower part of Lower Plagiostoma bed and Middle Ammonite bed, M., 1878	IX*a*.
351.	Overlying Upper Cannon-ball sandstone, Flag Hill to North Peak section, M., 1878	IX*a*.
352.	Middle Ammonite bed, Otapiri Creek, M., 1878	IX*a*.
353.	Middle Ammonite bed, slopes of Bare Hill, behind Taylor's Station, Lora Stream, M., 1878	IX*a*.
354.	Lower Ammonite bed, Taylor's Creek, junction of south branch; Flag Hill to North Peak section, M., 1878	IX*a*.
355.	Lower Ammonite bed, junction of Taylor's Creek and Otapiri, M., 1878	IX*a*.
356.	Below Lower Ammonite bed, junction of Taylor's Creek and Otapiri, M., 1878	IX*a*.
357.	Lower part of Lower Ammonite bed, Flag Hill to North Peak section, M., 1887	IX*a*.
358.	Lower part of Lower Ammonite bed, Taylor's Creek, below the woolshed, M., 1878	IX*a*.
359.	Lower Cannon-ball sandstone, Taylor's Creek, M., 1878 ..	X*a*.
360.	Below Lower Cannon-ball sandstone, Taylor's Creek, M., 1878..	X*a*.
361.	North-west branch of Taylor's Creek, above Trigonia beds, M., 1878	X*a*.
362.	Taylor's Crossing, Otapiri Creek, M., 1878	X*a*.
363.	Benmore Yards, M., 1878	X*a*.
364.	Trigonia beds, north-west branch of Taylor's Creek, M., 1878 ..	X*a*.
365.	Blue sandstone, north-west branch of Taylor's Creek, M., 1878	X*a*.
366.	Blue sandstone and chert, main branch of Taylor's Creek, M., 1878	X*a*.

	Locality.	Formation.
367.	Banks of the Otapiri Creek, one mile above Taylor's Crossing, M., 1878	X*a*.
368.	Trigonia beds, slopes of the southern peak of Benmore Range, M., 1878	X*a*.
369.	Benmore sandstone, south peak, Benmore Range, M., 1878	X*a*.
370.	Lowest bed of the Otapiri series, north-west branch of Taylor's Creek, M., 1878	X*a*.
371.	Benmore sandstone, Benmore railway-cutting, M., 1878	X*a*.
372.	Oreti railway cutting, M., 1878	X*a*.
373.	Monotis sandstone, Oreti Railway-station, M., 1878	X*b*.
374.	Monotis sandstone, southern peak of Benmore Range, M., 1878	X*b*.
375.	Monotis sandstone, north-west branch of Taylor's Creek, M., 1878	X*b*.
376.	Railway-cutting, north of Oreti Railway-station, M., 1878	X*b*.
377.	Ash-beds, North Peak section, M., 1878	XI*a*.
378.	Inoceramus beds, overlying Big Conglomerate, Oreti River, M., 1878	XI*a*.
379.	Spirigera beds, overlying Big Conglomerate, Oreti River, M., 1878	XI*a*.
380.	Spirifer and Crinoid beds, near Cowan's Railway-station, M., 1878	XI*c*.
381.	Spirifer and Crinoid beds, North Peak, M., 1878	XI*c*.
382.	Wairoa Gorge, M., 1875	X*b*.
383.	Mytilus problematicus bed, west side of Mount Wellington, Wairoa Gorge, M., 1878–79	X*b*.
384.	Halobia bed, east side of Mount Wellington, Wairoa Gorge, M., 1878–79	X*b*.
385.	Nautilus bed, east side of Mount Wellington, Wairoa Gorge, M., 1878–79	X*a*.
386.	Monotis sandstone, eastern slopes of Mount Wellington, Wairoa Gorge, M., 1878–79	X*b*.
387.	Mytilus problematicus beds, east slopes of Mount Wellington, Wairoa Gorge, M., 1878–79	X*b*.
388.	Limestone, Martin's saw-mill, upper end of Wairoa Gorge, M., 1878–79	XII*a*.
389.	Limestone, upper end of Wairoa Gorge, M., 1878–79	XII*a*.
390.	Spirifer beds, upper part of Spring Grove Creek, Wairoa Gorge, M., 1878	X*b*.
391.	Monotis sandstone, Spring Grove Creek, Wairoa Gorge, M., 1878	X*b*.
392.	Top of the range, head of Spring Grove Creek, Wairoa Gorge, M., 1878	X*b*.
393.	Lowest beds, Sellen's section, West Wairoa Gorge, M., 1878	X*b*.
394.	Spirigera beds, Sellen's section, Wairoa Gorge, M., 1878	X*b*.
395.	Mytilus problematicus beds, Sellen's section, Wairoa Gorge, M., 1878–79	X*b*.
396.	Great limestone, Sellen's, Wairoa Gorge, M., 1878–79	XII*a*.
397.	Productus limestone, Sellen's, Wairoa Gorge, M., 1878–79	XII*a*.
398.	Fossiliferous slates, Little Ben, Wairoa River, M., 1878	XII*a*.
399.	Fossiliferous slates, Dun Mountain Tramway, M., 1878	XII*a*.
400.	Upper Gorge of the Maitai River, M., 1878	XII*a*.
401.	Mount Potts Spirifer beds, M., 1877	XI*a*.
402.	Mount Potts Glossopteris beds, M., 1877	XI*a*.
403.	Seaward Downs, H., 1868	VIII*a*.
404.	Taylor's Creek (plants), M., 1878	IX*a*.
405.	Clent Hills (plants), Ha., 1872	VIII*a*.
406.	Mataura (plants), B., 1863; M., 1879	VIII*a*.
407.	Otapiri (plants), H., 1869	VIII.
408.	Owake Creek (plants), H., 1865	VIII*a*.
409.	Waikato Heads (plants), H., 1866	VIII.
410.	Pakawhau Coalfield (plants), H., 1868	VI*g*.
411.	Buller Coalfield, H., 1869	VI*f*.
412.	Grey Coalfield, H., 1869	VI*f*.
413.	Wangapeka, H., 1868	VI*f*.
414.	Shag Point, B., 1869	VI*f*.
415.	Mount Hamilton, H., 1869	VI*f*.

	Locality.	Formation.
416.	Whangarei (coal), H., 1866..	VI*f*.
417.	Kawakawa, H., 1866	VI*f*.
418.	Whangaroa, H., 1866	III*d*.
419.	Cromwell	VI.
420.	Landslip Hill (plants), H., 1869	VI.
421.	Mongonui (plants), H., 1866	II*c*.
422.	Knight's Hut, Malvern, H., 1869	VIII.
423.	Surveyors' Gully, Malvern, Ha., 1869	VI*f*.
424.	Jebson's Mine, Malvern, H., 1869	VI*f*.
425.	Trelissick (plants), H., 1872	VI*f*.
426.	Waikawa (plants), H., 1865	VIII*a*.
427.	Morley Creek and Linton, H., 1869	VI*f*.
428.	Abbey Rocks, C., 1875	VI.
429.	Mount Torlesse Annelid bed, H., 1869	XII*a*.
430.	Karori sandstone, Wellington, H., 1866	XII*a*.
431.	Graptolite slates, Collingwood	XIV*b*.
432.	Monotis beds, Eighty-eight Valley, Nelson, M., 1878	X*b*.
433.	Halobia beds, Eighty-eight Valley, Nelson, M., 1878	X*b*.
434.	Mytilus beds, Eighty-eight Valley, Nelson, M., 1878	X*b*.
435.	Psioidea beds, Eighty-eight Valley, Nelson, M., 1878	X*b*.
436.	Kaihiku beds, Eighty-eight Valley, Nelson, M., 1878	XI*a*.
437.	Nautilus beds, Mount Wellington, Wairoa Gorge, Nelson, M., 1878	X*a*.
438.	Monotis beds, Mount Wellington, Wairoa Gorge, Nelson, M., 1878	X*b*.
439.	Mytilus beds, Mount Wellington, Wairoa Gorge, Nelson, M., 1878	X*b*.
440.	Psioidea beds, Mount Wellington, Wairoa Gorge, Nelson, M., 1878	X*b*.
441.	Limestone, Martin's Mill, Wairoa Gorge, Nelson, M., 1878 ..	XI*a*.
442.	Mytilus beds, north side of Wairoa Gorge, Nelson, M., 1878 ..	X*b*.
443.	Psioidea beds, north side of Wairoa Gorge, Nelson, M., 1878 ..	X*b*.
444.	Graham River, Motueka Valley, Nelson, M., 1879	XIV*a*.
445.	Dart River, Wangapeka, Nelson, M., 1879	XIV*a*.
446.	Rolling River, Wangapeka, Nelson, M., 1879	XIV*a*.
447.	Rolling River, Wangapeka, Nelson, M., 1879	XIV*b*.
448.	Source of Clark River, Wangapeka, Nelson, 1879	XIV*a*.
449.	Lower beds, Trelissick Basin, Enys, 1880	VI*e*.
450.	Cape Rodney, Auckland, C., 1880	IV*b*.
450A.	Mount Brown beds, Coleridge Creek, Trelissick Basin, Enys ..	V*a*.
451.	Komiti Point, Kaipara, Auckland, C., 1880	VI*a*.
451A.	Pareora beds, Thomas and Porter Rivers, Trelissick Basin, Enys	IV.
452.	Mataura River, west bank, below falls, M., 1879	IV.
452A.	Plant-bed with shells, road-cutting, and Porter River, Trelissick Basin, Enys	IV.
453.	Mohaka River, Auckland, H., 1871	III*b*.
453A.	Upper surface of Mount Brown limestone, Trelissick Basin (old collection)	
454.	Kawakawa, Auckland, C., 1879	VI*e*, *f*.
454A.	Mount Brown limestone, Coleridge Creek, Trelissick Basin, M.	
455.	Monotis beds, Okuku Range, Canterbury, M., 1879	X*b*.
456.	Cretaceo-tertiary beds, Lake Wakatipu, Otago, M., 1880 ..	VI*e*.
456A.	Pareora bed, Thomas and Porter Rivers (old collection) ..	IV*b*.
457.	Pareora beds, Lake Wakatipu, Otago, M., 1880	IV*b*.
458.	Lower part of Pareora River, Canterbury, Enys, 1879 ..	IV*b*.
459.	Mouth of Wyndham River, Otago, M., 1879	IX*a*.
460.	Otapiri beds, Wharfdale, Ashley River, Canterbury, M., 1879 ..	X*a*.
461.	One mile below Mataura Falls, Otago, M., 1879	IX*a*.
462.	Baton River, near junction of the Clark River, Nelson, M., 1879	VI*e*.
463.	Near mouth of the Clark River, Baton River, Nelson, M., 1879	VI*d*.
464.	Limestone Island, Whangarei, Auckland, C., 1879	V.
465.	Opposite Captain Colbeck's, Kaipara, Auckland, C., 1880 ..	V.
466.	Clark's Cutting, Whakahara, Auckland, C., 1879	VI*a*.

	Locality.	Formation.
467.	Tangitiroria (Wilson's), Wairoa River, Auckland, C., 1879 ..	VII.
468.	Pareora beds, Wairoa Gorge, Nelson, M., 1878	IV*b*.
469.	Ostrea beds, south of Selwyn River, Malvern Hills, Canterbury, M., 1879	VI*f*.
470.	East bank of Mataura River, one and a half miles below bridge, M., 1879	VIII*c*.
471.	East bank of Mataura River, one mile below bridge, M., 1879 ..	VIII*c*.
472.	Popotuna Gorge, Otago (east end), M., 1879	XI*a*.
473.	Sellen's, Eighty-eight Valley, M., 1879	XII*a*.
474.	Limestone Bluff, Ashburton River, Canterbury, C., 1876 ..	V*a*.
475.	Mount Harris, Waihoa River, Canterbury, M., 1880	IV*b*.
476.	Kekenodon beds, Waitaki River, Otago, M., 1880	V*d*.
477.	Otakaika limestone, Station Peak, Waitaki, Otago, M., 1880 ..	V*c*.
478.	Otakaika limestone, Wharekauri, Waitaki, Otago, M., 1880 ..	V*c*.
479.	Marly greensands, Waihoa River, Canterbury, M., 1880 ..	VI*e*.
480.	Island sandstone, Waihoa River, Canterbury, M., 1880 ..	VI*e*.
481.	Otakaika limestone, Otakaika, M., 1880	V*c*.
482.	Waihoa limestone, Waihoa River, Canterbury, M., 1880 ..	VI*b*.
483.	Hutchinson's Quarry beds, Wharekauri, Waitaki Valley, Otago, M., 1880	V*b*.
484.	Maerewhenua limestone, Pigeon Rock, Waitaki Valley, Otago, M., 1880	VI*b*.
485.	Grey-marls, Waihoa River, Canterbury, M., 1880	VI*a*.
486.	Wharekauri greensand, Wharekauri, Waitaki Valley, Otago, M., 1880	VI*e*.
487.	Concretions with fossils overlying coal-beds, Ngapara, Waireka Valley, Oamaru, Otago, M., 1882	VI*e*.
488.	Limonitic sandstone (decomposed greensands), Government dam, Mount Ida Water-race, Naseby, Maniototo, Otago, M., 1883	VI*e*.
489.	Ototara limestone, Isolated Hill, north side of Kakanui Mouth, Oamaru, Otago, M., 1882	VI*b*.
490.	Volcanic breccia with shells under Ototara stone, Isolated Hill, North Kakanui Mouth, Oamaru, Otago, M., 1882	VIc. (?)
491.	Hutchinson's Quarry beds, Oamaru Creek, Town of Oamaru, Otago, M., 1882	V*b*.
492.	Hutchinson's Quarry beds, northern end of Awamoa Beach, Oamaru, Otago, M., 1882	V*b*.
493.	Pareora beds, Kyeburn (upper township) Diggings, Maniototo, Otago, M., 1883	IV*c*.
494.	Hutchinson's Quarry beds, Kyeburn (upper township) Diggings, Maniototo, Otago, M., 1883	V*b*.
495.	Ototara limestone, Cave Valley and upper part of Oamaru Creek, Oamaru, Otago, M., 1882	VI*b*.
496.	Maerewhenua limestone, crossing of Awamoko Creek, north of Ngapara, Oamaru, Otago, M., 1882	VI*b*.
497.	Marls overlying nummulitic limestone, Greymouth, Westland, M., 1882	IVc. (?)
498.	Marls under or = in part Ototara stone, cliffs on left bank of Kakanui River, opposite Maheno, Oamaru, Otago, M., 1882..	VI*b*, *c*.
499.	Marls under Ototara limestone, Cape Hills, northern end of Awamoa Beach, Oamaru, M., 1883	VI*c*.
500.	Marls under Ototara limestone, Cave Valley, Oamaru, M., 1883	VI*c*.
501.	Hampden (Onekakara) Beach and Moeraki Peninsula, Moeraki District, Otago, M., 1883	VI*e*.
502.	Coast Range (west slope), Cheviot Hills Station to Waiau-ua River, M., 1882	VI*e*.
503.	Chalk-marls, Happy Valley Creek, Motunau Flats, North Canterbury, M., 1882	VI*c*.
504.	Miocene beds, Happy Valley Creek, Motunau Flats, North Canterbury, M., 1882	IV*c*.
505.	Upper Miocene beds, near Cheviot Station, Cheviot Hills, Amuri District, Nelson, M., 1882	III*b*.

	Locality.	Formation.
506.	Swinburn, south-east corner of Maniototo Plain, Otago (calcareous sandstone), M., 1883	VI*b*.
507.	Green Valley, Upper Shag River, Waihemo, Otago, M., 1883 ..	VI*a*.
508.	Coal-beds, Reefton, Nelson (plants), M., 1882	VI*f*.
509.	Coal-beds, Brunnerton, Grey Valley, Nelson, M., 1882 ..	VI*f*.
510.	Bannockburn, Cromwell, Vincent County, Otago (plants), 1882	IV.
511.	Bannockburn, Cromwell, Vincent County, Otago, M., 1882 (shells and fish-remains)	IV. (?)
512.	St. Bathan's, Manuherikia Valley (plants), M., 1883	III. (?)
513.	Motutara Bluff, north shore of Kawhia Harbour, west coast of Auckland, M., 1884	VI*c*.
514.	Grey-marls, Kekerangu, Marlborough, M., 1884	VI*a*.
515.	Below limestone near Totara Point, south shore of Kawhia Harbour, west coast of Auckland, M., 1884	VI*c*.
516.	Waiherike River, south side of Kawhia Harbour, west coast of Auckland (belemnite beds), M., 1884	VIII*b*.
517.	Motutara Bluff, north shore of Kawhia Harbour, west coast of Auckland, M., 1884	VI*b*.
518.	Coverham, Clarence Valley, Marlborough, M., 1884	VI*g*.
519.	Kekerangu Creek, east coast of Marlborough (greensands), M., 1884	VI*e*.
520.	Flag Hill series, south shore of Kawhia Harbour, west coast of Auckland, M., 1884	VIII*c*.
521.	Takatahi, south shore of Kawhia Harbour, west coast of Auckland, M., 1884	VIII*b*.
522.	Putataka beds, north shore of Kawhia Harbour, west coast of Auckland, M., 1884	VIII*b*.
523.	Bastion series, coast between Kawhia Harbour and Albatross Point, west coast of Auckland, M., 1884	IX.
524.	Otapiri series, coast between Kawhia Harbour and Albatross Point, west coast of Auckland, M., 1884	X*a*.
525.	Wairoa series, coast between Kawhia Harbour and Albatross Point, west coast of Auckland, M., 1884	X*b*.
526.	Cretaceo-tertiary, Okoko, Waipa, Kawhia Road, Auckland, P., 1885	VI*b*, *c*.
527.	Shelly limestone, Hauturu, Waipa, Auckland, P., 1885 ..	VI.
528.	Putataka beds, Kohururu, Waingare, south-west of Auckland, P., 1885	VIII*b*.
529.	Taupiri Mine, Waikato River, Auckland, P., 1885	VI*f*.
530.	Beach, Hargreave's Run, opposite Komiti, Kaipara Harbour, Auckland, P., 1885	V.
531.	Strawberry Bay, Wairoa side of Komiti Peninsula, Kaipara Harbour, Auckland, P., 1885	V.
532.	Brown sand and gravel, Te Karaka, south side of Manukau Harbour, Auckland, P., 1885	II.
533.	Slate grit-bed, beach near Howick, Auckland, P., 1885 ..	
534.	Teredo bed, beach near Howick, Auckland, P., 1885	IV.
535.	Calcareous greensand, Onehunga, Auckland, P., 1885.. ..	IV.
536.	Teredo bed, Onehunga, Auckland, P., 1885	IV.
537.	Papakura limestone, Slippery Creek, Auckland, P., 1885 ..	VI*e*.
538.	Papakura limestone, Waikohu Creek, Auckland, P., 1885 ..	VI*e*.
539.	Volcanic breccia, coast near Lake Takapuna, Auckland, P., 1885	III*b*.
540.	Orakei Bay, Auckland, P., 1885	VI. (?)
541.	Maungamaungaroa Bridge, Howick, Auckland, P., 1885 ..	VI. (?)
542.	Komiti Point beds (Lower), Kaipara Harbour, Auckland, P., 1885	VI. (?)
543.	Komiti Point beds (Upper) or dirt-bed, Kaipara Harbour, Auckland, P., 1885	
544.	Greensands, Pahi, Kaipara Harbour, Auckland, P., 1885 ..	VI*e*.
545.	Ruamahunga Ferry (Gladstone), Wairarapa, Wellington, M., 1883	II*d*.
546.	Plant-beds, Clent Hills, Ashburton, Canterbury, M., 1877 ..	VIII*b*.
547.	Graptolite beds, Golden Ridge, Collingwood, Nelson, C., 1882 ..	XV*a*.
548.	Kawau Island, Auckland, C., 1880	IV. (?)

	Locality.	Formation.
549.	Curiosity Shop, Rakaia River, Canterbury, M., 1879	V*b*, VI*b*.
550.	Plants in clay associated with Wharekauri coal, Big Gully, Wharekauri, Waitaki Valley, Otago, M., 1881	III.
551.	Lottery Creek, Sherwood, Amuri District, Nelson, M., 1885 ..	V*a*.
552.	Triassic fossils from high-level river-terrace, Wharekauri, Waitaki Valley, Otago, M., 1881	X.
553.	Lake Te Anau, Southland, Otago, C., 1878	IV*c*.
554.	Heaver's Creek, Kekerangu, east coast of Marlborough, M., 1885	VI*a*.
555.	Waipapa Boat-harbour, Lower Clarence District, east coast of Marlborough, M., 1885	VI*a*.
556.	Sherwood, Lottery Creek, Amuri District, Nelson, M., 1885 ..	IV*c*.
557.	West Branch, Lottery Creek, Amuri District, Nelson, M., 1885	V*a*.
558.	Isolated Hills, Waiau-ua River, Amuri District, Nelson, M., 1885 (western part)	IV*c* or V.
559.	Black-birch Creek, Blairich, Awatere Valley, Marlborough, M., 1884	III*b*.
560.	Plant-beds, Quail Flat, Middle Clarence Valley, Marlborough, M., 1885	VI*f*.
561.	Grey-marls, Shades Creek, Kekerangu, Clarence, east coast of Marlborough, M., 1885	VI*a*.
562.	First gorge (Lower), Lottery Creek, Amuri District, M., 1885 ..	IV.
563.	Flaxbourne River, Cape Campbell District, Marlborough, M., 1884	IV*c*.
564.	Bluff Paddock, Dog Creek, Lyndon Station, Amuri, Nelson, M., 1885	IV*c* or V.
565.	Central part of Isolated Hills, Waiau, Amuri District, Nelson, M., 1885	IV*b*.
566.	Highfield Ridge, east side of Waiau, Amuri District, Nelson, M., 1885	IV*b*. (?)
567.	Below "Gates," Mason River, Waiau, Amuri, Nelson, M., 1885	IV*b*.
568.	Quail Flat, Middle Clarence Valley, Marlborough, M., 1885 ..	VI*f*.
569.	Weka Pass stone, Seymour River, Middle Clarence Valley, Marlborough, M., 1885	VI*b*.
570.	Amuri beds, Seymour River, Middle Clarence Valley, Marlborough, M., 1885	VII.
571.	Quail Flat, Middle Clarence Valley, Marlborough, M., 1885 (freshwater shells)	VI.
572.	Black-grit, Seymour River, Middle Clarence Valley, Marlborough, M., 1885	VI*g*.
573.	Kiwi Range, north side of Mohaka Valley, Napier, M., 1885 ..	IV*b*.
574.	Upper shelly limestone, Scinde Island, Napier, M., 1885 ..	II*a*.
575.	Pohui limestone, Te Waka Range, south-east side of Mohaka Valley, Napier, M., 1885	III*a*.
576.	Scinde Island, Napier, lowest beds (shelly limestones), M., 1885	II*a*.
577.	Pareora beds, Kakahu River, South Canterbury, P., 1885 ..	IV*b*.
578.	Greensands under Weka Pass stone, Kakahu River, South Canterbury, P., 1885	VI*e*.
579.	Weka Pass stone, Kakahu Valley, South Canterbury, P., 1885	VI*b*.
580.	Rangitaumau Hill, Taueru Road, Masterton, Wairarapa, Wellington, P., 1886 (limestone)	III*b*.
581.	Below limestone, Rangitaumau Hill, Taueru Road, Masterton, Wairarapa, Wellington, P., 1886	III*b*.
582.	Blue clays, Urenui, Waitara, Taranaki, P., 1886	II.
583.	Pareora beds, Onairo, Waitara, Taranaki, P., 1886	IV.
584.	Greensands under foraminiferous limestone, Mokau River, south-west of Auckland Provincial District, P., 1886	VI.
585.	Greensands under limestones (Balanus), Birch's, Kaimanawa Range, Wellington, P., 1886	III*b*.
586.	Plant-sandstone under Balanus limestone, Birch's, Kaimanawa Range, Wellington, P., 1886	III.
587.	Balanus limestone, Kaimanawa Range, Wellington, P., 1886 ..	III*b*.
588.	Waitotara, Puketapu, Wellington, H., 1886 (bed contains *Ostrea ingens*)	III*b*.

	Locality.	Formation.
589.	Selwyn Rapids, Selwyn River, Malvern Hills, Canterbury, M., 1886	VI*e*.
590.	Selwyn River, north-east bank below rapids, Malvern Hills, Canterbury, M., 1886	VI*e*.
591.	Railway bridge near Sheath's Coalmine, Selwyn River, Malvern Hills, Canterbury, M., 1886	VI*e*.
592.	Shag Point, Otago, beach opposite coalmine and near McIntosh's store, M., 1886	VI*e*.
593.	Mount Puke Iwitai, Lower Shag Valley, Otago, M., 1886	VI*e*.
594.	Little Puke Iwitai, Woolshed Creek, Lower Shag Valley, Otago, M., 1886	VI*e*.
595.	Middle of north side of Moeraki Peninsula, Moeraki District, Otago, M., 1886	VI*e*.
596.	Onekakara (Hampden) Beach, North Moeraki Bay, one to two miles north of Hampden, Moeraki, Otago, M., 1886	VI*e*.
597.	Onekakara (Hampden) Beach, one mile south of White Bluff, Moeraki, Otago, M., 1886	VI*e*.
598.	Dunback and Grange (Kitchener's), Shag Valley, Otago, M., 1886	VI*e*.
599.	Guffie's Quarry, Carsphairn, Janet's Peak, Shag Valley, Otago, M., 1886	VI*d*.
600.	Ototara limestone, south side of estuary, Kakanui mouth, Kakanui, Oamaru, Otago, M., 1886	VI*b*.
601.	Deer Park Spur (north-west end of), Bushy Park, south side of Lower Shag Valley, Otago, M., 1886	V*b*.
602.	Seaward Ridge, south side of estuary of Pleasant River, Hawksbury District, Otago, M., 1886	V*b*.
603.	Middle Mountain, source of Pleasant River, Palmerston, Otago, M., 1886	VI*e*.
604.	Muir's Creek, between Harry's Peak and Shag River, Shag Valley, Otago, M., 1886	VI*e*.
605.	Calcareous sandstone, Tumai, Hawksbury District, Otago, M., 1886	VI*b*.
606.	Maheno marls, left bank of Kakanui River, opposite Maheno Railway-station, Oamaru, Otago, M., 1886	VI*b*, *c*.
607.	Anderson's farm, Puketapu, to sea at Goodwood Lagoon, Palmerston, Otago, M., 1886	VI*a*.
608.	Between south end of Mount Royal and sea at Bobby's Head, Palmerston, Otago, M., 1886	VI*a*.
609.	Scroggs's Hill, near Saddle Hill, east side of Taieri Plain, Otago, M., 1886	VI*e*.
610.	Grey-marls, mouth of Seymour River, Middle Clarence Valley, Marlborough, M., 1885	VI*a*.
611.	Grey-marls, Muzzle River, Middle Clarence Valley, Marlborough, M., 1886	VI*a*.
612.	Grey-marls, Dart River, Middle Clarence Valley, Marlborough, M., 1886	VI*a*.
613.	Great Post-miocene conglomerate, Bluff River, Clarence Valley, Marlborough, M., 1885	II.
614.	Black-grit, Coverham, Middle Clarence Valley, Marlborough, M., 1885	VI*f*.
615.	Bluff River (junction with Clarence), Middle Clarence Valley, Marlborough, M., 1886	VII.
616.	Red Hill Creek Bluff, Middle Clarence Valley, Marlborough, M., 1885	VI*g*.
617.	Grey-marls, Bluff River, Middle Clarence Valley, Marlborough, M., 1885	VI*a*.
618.	Weka Pass stone, Bluff River, Middle Clarence Valley, Marlborough, M., 1885	VI*b*.
619.	Kaikoura Peninsula, Marlborough, M., 1886 (Grey-marls)	VI*a*.
620.	Calcareous sandstone, Puketapu, Palmerston, Otago, M., 1886	VI*b*.
621.	Seacliffs, Bushy Park, south of mouth of Shag River, Otago, M., 1886	IV*c*.

	Locality.	Formation.
622.	Katiki (Katiki Beach, half a mile north of Shag Point Railway-station), Moeraki, Otago, M., 1886	VI*e*.
623.	White Bluff, between north end of Onekakara Beach and mouth of Otepopo River, Moeraki, Otago, M., 1886	VI*c*. (?)
624.	Hutchinson's Quarry beds, over Ototara limestone, All-day Bay, one mile south of Kakanui mouth, Oamaru, Otago, M., 1886	V*b*.
625.	Pareora beds (=Awamoa beds), All-day Bay, south of Kakanui, Oamaru, Otago, M., 1886	IV*c*.
626.	Junction between Ototara limestone and dirty groensand representing Hutchinson's Quarry beds, All-day Bay, one mile south of Kakanui, Oamaru, Otago, M., 1886	V*b*. (?)
627.	Isolated limestone hill, Limekiln Hill, Kakanui Township, Oamaru, Otago, M., 1886	VI*b* or *c*.
628.	Belemnitella beds, Brighton, Saddle Hill, Dunedin, Otago, M., 1886	VI*e*.
629.	Waihola Township, Waihola, Otago, M., 1886	IV. (?)
630.	Concretionary sands overlying Mokau coal, Mokau River, Auckland, P., 1886	VI.
631.	Plant-beds under Shag Point coal, Shag Point, to mouth of the Shag River, M., 1886	VI*f*.
632.	Tertiary beds on coast at Bobby's Head, Palmerston, Otago, M., 1886	IV*c*.
633.	Blue clays, mouth of Kai-iwi River, Wanganui, P., 1886 ..	II*b*.
634.	Shell-beds, mouth of Butler's Creek, Waitotara, P., 1886 ..	II*c*.
635.	Rotella beds, Nukumaru Beach, Waitotara, P., 1886	II*d*.
636.	Nukumaru limestone, Waitotara, P., 1886	II*d*.
637.	Between West Wanganui and Mokihinui, Nelson, H., 1886 ..	VI*f*.
638.	Kaiwaiki quarries, Wanganui River, P., 1886	II*d*.
639.	Ostrea ingens bed, Waitotara, P., 1886	III*a*.
640.	Blue clays on coast north of Waitotara River, P., 1886 ..	III*a*.
641.	Blue clays, Wairoa Beach, Waitotara, P., 1886	III*a*.
642.	Waihao Bridge, one and a half miles below the Forks, M., 1886	VI*f*.
643.	Amuri limestone, Weka Creek, Weka Pass, M., 1886	VI*d*.
644.	Blue clays, Patea, P., 1886	III*b*.
645.	Blue clays, Pipiriki, Wanganui River, P., 1886	III*b*.
646.	Coal greensands, Mokau River, P., 1886	VI*f*.
647.	Utapu, Upper Wanganui River, P., 1887	III*a*.
648.	Otapokiore, Upper Wanganui River, P., 1887	III*b*.
649.	Paparoa Rapids, Upper Wanganui River, P., 1887	V*a*.
650.	Blue clays, Paparoa Rapids, Upper Wanganui River, P., 1887..	VI*a*.
651.	Yellow sandy clays, Ongaruhe Valley, P., 1887	VI*a*.
652.	Greensands, Ongaruhe Valley, P., 1887	VI*f*.
653.	Heao Valley, Upper Wanganui, P., 1887	III*a*.
654.	Mangapahoe, Mokau River, P., 1887	VI*f*.
655.	Limestone, near Totoro, Mokau River, P., 1887	VI*b*.
656.	Yellowish clays, Mokau Gorge, near Totoro, P., 1887 ..	VI*a*.
657.	Limestone, Te Ruangaruhe, near Totoro, P., 1887	VI*b*.
658.	Limestone, Wairere Falls, Upper Mokau, P., 1887	VI*b*.
659.	Limestone, Pipiriki, Upper Wanganui, P., 1887	III*a*.
660.	Limestone at Caves, near Mangaio, Upper Wanganui, P., 1887	III*a*.
661.	Secondary rocks, Awakino Valley, P., 1887	VIII*a*.(?)
662.	Limestone, Tata Island, Nelson, H., 1887	III*a*.
663.	Limestone, Awakino Valley, P., 1887	VI*b*.
664.	Limestone on range, head of Mangatawa, Mokau River, P., 1887	VI*b*.
665.	Shales one and a half miles below Mataura Falls, Southland, P., 1887	VIII*a*.
666.	Plant-beds, below upper conglomerate, at waterfall, head of left branch of Lora, Hokonui Hills, P., 1887	VIII*a*.
667.	Lower plant-beds, Dunsdale, Hokonui Hills, P., 1887 ..	VIII*a*.
668.	Plant-beds, Hedgehope, Hokonui Hills, P., 1887	VIII*a*.
669.	Plant-beds, McRae's, Makarewa, Hokonui Hills, P., 1887 ..	VIII*a*.
670.	Plant-beds, Coal Creek, Otapiri Gorge, Hokonui Hills, P., 1887	VIII*a*.
671.	Plant-beds, top of Flag Hill, Hokonui Hills, P., 1887	VIII*a*.

	Locality.	Formation.
672.	Plant-beds, Otapiri Gorge, near Conical Hill, P., 1887	VIII*a*.
673.	Highest Spirifer grit, Otapiri Gorge, P., 1887	VIII*b*.
674.	Tachylite breccias, Oamaru Breakwater, P., 1886	V*a*.
675.	Waireka tufas, Teaneraki, Oamaru, P., 1886	VI*c*.
676.	Coal greensands, Livingstone line, Oamaru, P., 1886	VI*f*.
677.	Plant-beds, South Head, Waikawa, P., 1886	VIII*a*.
678.	Plant-cherts, Landslip Hill, Waipahi, Otago, P., 1886	VI*f*.
679.	Waihou Bay, Bay of Plenty, M., 1887	II*c*.
680.	Mohaka crossing, Te Purutu Creek, Napier, M., 1887	III*b*.
681.	Pumice-sands, Kaiwaka Station, Esk Valley, Napier, M., 1886	II*c*.
682.	Shelly limestone, Raukokore, Bay of Plenty, M., 1887	III*a*.
683.	Esk River, Napier, M., 1886	II*c*.
684.	Akuakua, Waipiro Bay, east coast of Auckland, M., 1887	IV*c*.
685.	Akuakua, Venus beds, east coast of Auckland, M., 1887	IV*c*.
686.	Waipiro Creek, east coast of Auckland, M., 1887	IV*c*.
687.	Pumice-sands, mouth of Mohaka River, M., 1887	II*c*.
688.	Secondary beds, Awanui, M., 1887	VI*f*.
689.	Raised beach, Mahia Peninsula, M., 1887	I*d*.
690.	Clays under Petane limestone, Petane, M., 1887	II*b*.
691.	Petane limestone, Petane, M., 1887	II*a*.
692.	Secondary rocks, Waipawa Gorge, M., 1886	VI*e*.
693.	Under Te Aute limestone, south-east corner Ruataniwha Plain, Hawke's Bay, M., 1886	III*b*.
694.	South-east slopes of Mount Vernon, Napier, M., 1886	III*e*.
695.	Tertiary beds, Motutapu Island, P., 1887	IV*c*.
696.	Gibson's, Te Ope Creek, Pahi, Kaipara, P., 1887	VI*f*. (?)
697.	Volcanic grit, Cheltenham Beach, North Shore, Auckland, P., 1887	IV*c*.
698.	Greensands below limestone, Colbeck's Landing, Pahi, Kaipara, P., 1887	VI*f*.
699.	Limestone, Colbeck's, Pahi, P., 1887	VI*e*.
700.	Beds below hydraulic limestone, Batley, Kaipara, P., 1887	VI*d*.
701.	Parnell grit, Judge's Bay, Auckland, P., 1887	IV*c*.
702.	Lower limestone, Scinde Island, M., 1887	III*a*.
703.	Te Whaka Range, west of Pohui, Napier, M., 1887	II*a*.

In the previous issue of this list the following numbers were unfortunately duplicated, which has led to some confusion respecting them in a paper by Professor Hutton on the geology of the Trelissick Basin (Trans. N.Z. Inst., Vol. XIX.). The numbers duplicated are 450, 451, 452, 453, 454, and 456, which, where they apply to localities in the Trelissick Basin, should read 450A, 451A, 452A, 453A, 454A, 456A, respectively.

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Colonial Museum and Geological Survey of New Zealand.

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DIRECTOR.

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